

UNIVERSITY OF ALBERTA

**FORENSIC TAPHONOMY IN A COLD CLIMATE REGION:
A FIELD STUDY IN CENTRAL ALBERTA AND A POTENTIAL NEW
METHOD OF DETERMINING TIME SINCE DEATH**

by

DEBRA KOMAR



A thesis submitted to the Faculty of Graduate Studies and Research in partial
fulfillment of the requirements for the degree of Doctor of Philosophy

Department of Anthropology

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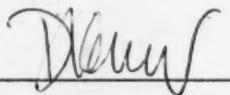
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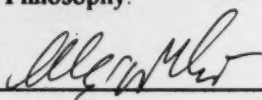
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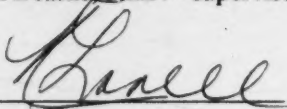
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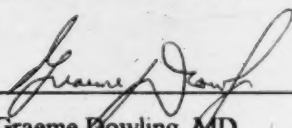
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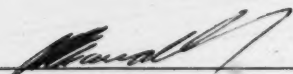
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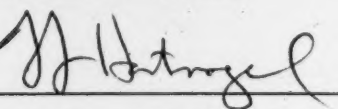
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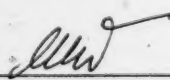
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ABSTRACT

This study represents the first analysis of taphonomic processes relevant to forensic investigations from a cold climate region, with a three phase research design that incorporates historical record reviews, animal analogy decomposition field studies, and search strategy field experimentation. Results of this study provide background for preliminary research and development of a histological method of estimating time since death.

In phase one, two separate record surveys were conducted at the Office of the Chief Medical Examiner in Edmonton, Alberta. The first examined cold weather decay rates; the second focused on cases involving hanging as the cause of death, with particular emphasis on outdoor and decomposed cases.

In phase two, a 20 month field study examining decomposition and scavenging was undertaken at two research facilities in the Edmonton area. Domestic pigs (*Sus scrofa*) were used as models for humans and were allowed to decay naturally under daily observation. Significant findings presented are: 1) the effects of carcass size on decay rates in shaded and sun exposed carrion; 2) observations that postmortem insect activity may mimic perimortem sexual assault clothing patterns; and 3) methods of identifying bird scavenging in fleshed and dry remains. Comparison of field study observations with record review results and case studies assesses the validity of animal analogues in human decomposition studies.

Results of both the field study and record reviews reveal a high incidence of animal scavenging in this region. Disarticulation and dispersal of remains by animals,

combined with heavy snowfalls, confound search and recovery of remains and require innovative search strategies. In phase three, the results of field trials using specially trained "cadaver" dogs suggest that they are highly effective in locating dispersed human remains, particularly in snow.

Regional factors such as cold weather and intense animal scavenging render entomological methods of estimating time since death (TSD) ineffective. Preliminary investigations into a new histological method of determining TSD, which may prove less environmentally sensitive, are presented. Autolytic and putrefactive changes to the proteoglycans and Type II collagen of the nucleus pulposus of lumbar intervertebral discs may serve as indicators of postmortem interval.

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1. INTRODUCTION, LITERATURE REVIEW, AND RESEARCH DESIGN

1.1 INTRODUCTION

This thesis represents the first examination of taphonomic processes relevant to forensic investigations from a cold climate region. Forensic taphonomy is the application of traditional taphonomic models, approaches and analyses to forensic investigations in order to estimate the postmortem interval, reconstruct the sequence of events before and after deposition, and differentiate the products of perimortem human actions from natural postmortem artifacts (Haglund and Sorg, 1997a).

Although it shares many of the same methods and principles as forensic anthropology, forensic taphonomy places greater emphasis on soft tissue decomposition and analysis, and focuses equally on the recovery scene and the body. While the primary task of a forensic anthropologist is to identify the individual (Mann and Ubelaker, 1990), the function of the forensic taphonomist is to identify what happened to the body between death and recovery (Haglund, 1991):

1.2 REVIEW OF THE LITERATURE

1.2.1 Forensic Taphonomy and Decay Rates

The study of forensic taphonomy, and even the phrase itself, is of recent origin. The keyword "taphonomy" does not appear in the *Journal of Forensic Sciences* until 1989 (Haglund, 1991) and the first textbook dedicated exclusively to forensic taphonomy was published last year (Haglund and Sorg, 1997b). Despite its roots in forensic anthropology, there is little historical literature relating directly to forensic

taphonomy, and only brief mentions of "taphonomic analysis" in standard forensic anthropological textbooks (Krogman and Iscan, 1986; Stewart, 1979).

The current literature is restricted to anecdotal case studies from specific geographic locations (Haglund, 1991). Virtually all published reports are from the United States, primarily Tennessee (Bass, 1997; Watkins, 1983; Mann *et al.*, 1990; Rodriguez and Bass, 1985) and Washington State (Haglund *et al.*, 1989; Haglund 1991, 1992, 1993). Only two long-term field studies have been reported: the human cadaver decomposition studies in Tennessee (Rodriguez and Bass, 1985; Watkins, 1983; Mann *et al.*, 1990) and Project PIG in Colorado (France *et al.*, 1992, 1997). To date, no taphonomic field studies have been conducted in Canada or any similar cold climate region.

The research indicates that numerous factors affect decomposition rates: temperature, humidity, rainfall, perimortem trauma, insect activity, burial, scavenging, body size, depositional surface, and clothing (Mann *et al.*, 1990). Haglund (1993) demonstrates that decay times and disarticulation sequences of human remains differ in land and water depositions. Water temperature was also found to play a significant role in the rates of decay and disarticulation, while clothing tended to speed up tissue disappearance yet retard disarticulation (Haglund, 1993). Adipocere formation in water immersed bodies has been shown to greatly reduce decomposition in the underlying tissues (Rothschild *et al.*, 1996; Cotton *et al.*, 1987). Preliminary animal analogy work has been conducted on the effects of freezing on decay rates and soft tissue preservation (Micozzi, 1997, 1986). A final important factor influencing

decomposition rates is sun exposure. Decay rates in sun exposed and shaded environments were shown to vary dramatically because of associated insect activity (Shean *et al.*, 1993).

Variables which influence decomposition rates must therefore be considered variables which impact estimates of the time since death. Results of case report surveys or field studies are specific to their geographic region and extrapolation of data into differing geoclimatic zones must be done with extreme caution. The differing decay rates observed in various climatic zones and geographic areas suggest that not all methods of postmortem interval estimation are equally appropriate or applicable to all regions.

1.2.2 Time Since Death Estimation

I feel that at present the time of death resembles somewhat the value attributed in some people's minds to the lie detector. An excellent investigational instrument but not of such great value as an evidential weapon.
(Camps, 1959: 79-80).

Numerous methods for establishing the time since death have been studied, especially those dealing with short-range postmortem interval (the period up to 200 hours after death), while only a few less accurate methods have been proposed for extended postmortem intervals (Gallois-Montbrun *et al.*, 1988). "As the PMI increases, the accuracy of its determination necessarily decreases" (Schoenly *et al.*, 1991: 1395). Early critics of time since death estimation methods felt that the estimates given were so flawed and wide-ranging as to allow for "...the farcical... possibility of the person still being alive" (Camps, 1959:78) and that establishing the

postmortem period should be seen as more a matter of estimation rather than determination (Van Den Oever, 1976).

Research with the aim of producing accurate methods of determining the time interval since death has only recently begun, although the emphasis continues to be on estimating short-range intervals. Methods currently employed to establish short-range PMI include rectal temperature (Henssge, 1988; Knight, 1986; Marshall and Hoare, 1962), white cell counts (Babapulle and Jayasundern, 1993), vitreous humour creatine levels (Piette, 1989), electrical excitability of skeletal muscle (Madea, 1992), and free amino acid content (Mel'nikov and Alybaeva, 1995). Attempts to use nasal or auditory canal temperatures proved highly unsatisfactory (Nokes *et al.*, 1992). Computer programs have been developed to estimate the postmortem interval using decreasing body temperature in both humans (Lynnerup, 1993) and wildlife (Cox *et al.*, 1994).

Short-range time since death estimates have been derived from four characteristics of white blood cells: total and differential cell counts, differential degeneration and morphology of cells (Babapulle and Jayasundern, 1993). The method is considered "reasonably exact" for a PMI of up to 84 hours (Babapulle and Jayasundern, 1993: 213). Known fluctuations in melatonin levels in the pineal body throughout the day have been used to determine whether death occurred during the day or night, but with only marginal success (Mikami, 1993).

Traditional methods of estimating short-range PMI focused on the triad of lividity, rigor mortis and algor mortis (Van Den Oever, 1976). A recent attempt to quantify

the degree of lividity lead to the development of an instrument which measures subcutaneous hemoglobin concentrations; the method has produced significant correlation between known PMI and estimations based on instrumental lividity measurement (Inoue *et al.*, 1994). Sweat gland morphology has also been explored as an indicator of early PMI. The simultaneous testing of cytochemical, immunohistochemical and ultrastructural characteristics of sweat glands have produced fairly accurate PMI estimates for the first 12 hours following death (Cingolani *et al.*, 1994). Finally, observations of an increase in the number of cells in cerebrospinal fluid after death prompted a study which developed a predictive mathematical expression of the increase over time (Wyler *et al.*, 1994). It is not known whether the cell increase is exclusively a postmortem phenomenon and additional research is required.

Midrange postmortem intervals (up to 30 days following death) have been investigated using soft tissue biochemical studies in animal models (Gallois-Montbrun *et al.*, 1988), but with limited success. Piette (1989) found a correlation between increasing creatine levels in vitreous humour and the postmortem interval, the estimates becoming more accurate in cases with a PMI of three days or longer.

Free amino acid content in liver and lung samples of cadavers with a PMI of two weeks has been measured using high-performance liquid chromatography (Mel'nikov and Alybaeva, 1995). The cadavers were maintained at moderately high temperatures (18 to 23 degrees C) in 40 to 60% humidity for 14 days prior to testing. Microblocks

of the five most informative and stable amino acids produced estimates with 95% reliability (Mel'nikov and Alybaeva, 1995).

One of the first, and simplest, mid to long-range TSD studies was conducted at the University of Tennessee research facility using three male cadavers. The timing and sequence of gross postmortem changes to the cadavers was recorded for up to one year; however, the sequence and rate of change among the cadavers was considered too variable to produce accurate TSD estimates (Watkins, 1983).

Mid to long-range TSD estimates have been attempted using putrefying muscle tissue and electron paramagnetic resonance. Samples were tested at one week intervals from 7 to 182 days following death and results suggest the method may be useful in conjunction with other estimating methods (Zharov, 1996).

Volatile fatty acids deposited in soil underneath decomposing human remains have also been used to establish mid and long range time since death. Vass *et al.* (1992) find that, for their local climate, skeletonization of a corpse occurs in 1285 ± 110 accumulated degree days (ADD). They propose a method which compares the amount of volatile fatty acids in the soil solution beneath remains with an estimate of the living weight of the individual to determine the number of ADD. Comparisons of the ADD with regional weather records produces an estimate of the time since death. The method has proven reasonably accurate in the two case studies cited, although temperature and precipitation were shown to affect results (Vass *et al.*, 1992).

Reliable PMI estimates, even in cases involving advanced decomposition, have been given using entomological indicators (Goff and Odom, 1987). An excellent

review of the history of forensic entomology can be found in Catts and Goff (1992). Research on carrion associated species has been conducted on every continent (Schoenly *et al.*, 1991); however, data collection reports in Canada are currently limited to British Columbia (Anderson and VanLaerhoven, 1996). Although entomology has been used with some success in British Columbia (Skinner *et al.*, 1988; Anderson, 1995; Anderson and VanLaerhoven, 1996), its reliability in the rest of Canada has yet to be proven. Central Alberta experiences mean monthly temperatures below freezing five months of the year (Komar, 1998), resulting in minimal to no insect activity for half of each year. This raises serious concerns as to the method's utility in this region.

Plant growth and root formation can provide information on the postmortem interval (Willey and Heilman, 1987), although such indicators must be used with caution as there is no standard rates in root growth, even for roots of the same plant (Quartehomme *et al.*, 1997). Plant growth can, at best, estimate the minimal time since death as plant infiltration of remains may be secondary after decomposition or the moving of the body postmortem (Quartehomme *et al.*, 1997). Again, the cold temperatures and restricted growing seasons of Alberta limit the utility of this method in this area.

1.2.3 Postmortem Animal Scavenging

Postmortem scavenging of remains by animals may accelerate decomposition (Komar, 1998), modify scenes, alter or disperse remains and destroy indicators of

identity and cause of death (Haglund, 1992). The majority of the literature focuses on the actions of carnivores (Binford, 1981; Blumenschine, 1986; Hill, 1979), primarily canids (Willey and Snyder, 1989; Haglund *et al.*, 1988; Milner and Smith, 1989; Haglund *et al.*, 1989; Haglund, 1997a). Postmortem alterations to remains have also been attributed to rodents (Haglund, 1992, 1997a), domestic pets (Rossi *et al.*, 1994; Rothschild and Schneider, 1997) and sharks (Rathbun and Rathbun, 1997).

Haglund (1991) examines the following five aspects of carnivore scavenging: 1) soft tissue damage and consumption sequences, 2) disarticulation of remains, 3) dispersal and accumulation of bone, 4) patterns of bone modification and 5) skeletal element survival frequencies. Variables affecting carnivore scavenging include tissue thickness (Haynes, 1980), bone architecture, the length of postmortem interval (i.e. the "freshness" of the remains), body position, rigor mortis and freezing, proximity of remains to human activity and clothing (Haglund, 1997a).

Rodents are among the most common scavengers of human remains (Haglund, 1992). Haglund (1992, 1997c) describes the distinct parallel stria characteristic of rodent gnawing on bone and identifies rodents as important vectors of transport and modifiers of scenes. Haglund also presents a case study detailing the use of decayed human remains as a rodent's nest (1992, 1997c).

Postmortem animal interactions with human remains are not restricted to bodies located out of doors. Scavenging by indoor domestic pets (cats and dogs) has received some attention (Rossi *et al.*, 1994; Rothschild and Schneider, 1997). Often, the modifications produced by pets raise suspicions of criminal activity (Rothschild and

Schneider, 1997). Reports are not limited to cats and dogs; injuries inflicted by a hamster (Ropohl *et al.*, 1995) and chickens (Roll and Rous, 1991) are also described.

1.2.4 Search Strategies and Recovery of Remains

Scavenging, dispersal of remains by human, environmental or animal agents and weather conditions such as snowcover complicate death scenes and confound recovery efforts. The lack of a forensic anthropologist or similarly trained personnel at the scene can lead to collection bias, loss of information and incomplete recovery of remains (Warren, 1984; Haglund *et al.*, 1990; Howard *et al.*, 1988; Haglund, 1991). Additional complications may arise when remains are separated by great distances, are recovered at different times (Haglund and Reay, 1993), or are buried (Owsley, 1995; Bevan, 1991; Hoving, 1986; Imaizumi, 1974).

Scene protocols and search strategies have only recently received mention in the literature. The majority focus on strategies for locating clandestine burials (Owsley, 1995; France *et al.*, 1997; Bethell and Carver, 1987; Boyd, 1979; Hoving, 1986; Imaizumi, 1974; Killam, 1990; McLaughlin, 1974; Mellet, 1992; Miller, 1996; Rodriguez and Bass, 1985; Wychoff, 1986). Suggested methods include: probes (Owsley, 1995), ground penetrating radar (Mellet, 1992; Miller, 1996), remote sensing and aerial photography (Killam, 1990). A long term animal analogy field study is currently underway in Colorado which tests 15 different methods of detecting clandestine burials, including thermal imaging, soil gas and cadaver dogs (France *et al.*, 1997, 1992).

Search strategies and recovery protocols have also been suggested for surface deposited bodies. Because of the importance of dentition in establishing positive identification, Haglund (1997b) provides search strategies designed to maximize recovery of dental remains in cases involving scattered skeletal remains. Further suggestions for recovering scavenged remains include utilizing faunal evidence such as scat and tracks to locate widely dispersed skeletal elements (Murad, 1997). A field experiment using radio transmitters to track bones from scavenged pig carcasses found that bones were transported over 400 m from the original depositional site and that reburial of remains by scavengers was not uncommon (Adair and Kolz, 1998).

1.3 RESEARCH OBJECTIVES AND DESIGN

This study represents the first examination of forensic taphonomy in a cold climate region. The principle objectives of this research are to establish cold climate decay rates and identify variables affecting decompositional rates and sequences, to describe natural taphonomic processes which modify remains or the scene, and to develop search strategies specific to cold weather environments. As one of the primary goals of forensic taphonomy is to estimate the length of the postmortem interval, findings from this study aided in the preliminary development of a potential new method of determining time since death compatible with cold climate regions.

This study utilizes a three phase research design. Phase one examines historical case reports from the region to provide background and establish parameters for field studies. Two separate record reviews were conducted at the Office of the Chief

Medical Examiner in Edmonton, Alberta. The first examines year-round rates of decay and skeletonization for the Edmonton area. The second focuses on cases involving hanging as the cause of death and provides statistical information on manner of death, location of body recovery and the length of the postmortem interval.

In Phase two, a 20 month field study was undertaken at two research facilities in the Edmonton area. Domestic pigs (*Sus scrofa*) were used as models for humans and were allowed to decay naturally under daily observation. Information was recorded on variables identified in the records surveys as having a significant impact on decay rates, such as scavenging and depositional environment. Direct comparison of the animal analogues to human case studies and record survey results provides the basis for evaluating the validity of animal models in this type of experimentation.

Disarticulation and dispersal of remains as a result of animal scavenging, combined with heavy snowfalls or deciduous leafcover, confound search and recovery efforts in northern climates and require innovative search methods. Phase three used findings from the first two phases to develop search strategies which maximize skeletal element recovery given the environmental conditions of the region. Field studies conducted as part of a joint research and training program with the Royal Canadian Mounted Police (RCMP) Police Dog Service examine the potential of specially trained cadaver air scent detection dogs to locate isolated and fragmentary remains under a variety of climatic and environmental conditions.

Regional factors such as cold weather render entomological methods of estimating the postmortem interval ineffective. In the appendix, a new histological method of

determining TSD is proposed which may prove less environmentally sensitive. Results from the previous research phases suggest that intervertebral discs have a high recovery rate. Postmortem changes to the biochemical components of the discs may serve as indicators of postmortem interval.

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2. DECAY RATES IN A COLD CLIMATE REGION: A REVIEW OF CASES INVOLVING ADVANCED DECOMPOSITION FROM THE MEDICAL EXAMINER'S OFFICE IN EDMONTON, ALBERTA¹

2.1 INTRODUCTION

Recently, there has been an increase in the number of studies investigating methods of estimating middle and long range postmortem interval (PMI) (Galloway *et al.*, 1989; Mann *et al.*, 1990; Rodriguez and Bass, 1985; Schoenly *et al.*, 1991; Vass *et al.*, 1992). However, these studies have been conducted in the southern United States, primarily at the Anthropology Research Facility at the University of Tennessee, and are restricted in their application to temperate weather regions. Similar studies in cold weather climates typical of the northern United States and Canada have not been widely reported.

To provide background in preparation for such a study, a review of cases involving advanced decomposition was undertaken at the Office of the Chief Medical Examiner in Edmonton. Edmonton is located in central Alberta at an elevation of 671 meters (2198 ft). The city experiences an average annual temperature range of -17°C to 16 °C, with mean monthly temperatures below freezing for five months of the year (see Table 2.1). Average annual rainfall is 33 centimeters (13 in.) and average annual snowfall is 132 centimeters (53 in.) (Environment Canada, 1990-1996).

The purpose of the review was to establish methodological parameters for subsequent field experimentation in this climate region, such as determining the types of environments from which bodies are recovered. Data were gathered on the age and sex of the

¹ A version of this chapter has been published. Komar, DA 1998. *Journal of Forensic Sciences* 43(1):57-61.

TABLE 2.1

*Mean Monthly Temperature in Degrees Celcius from
Edmonton Municipal Airport for the years 1993-1996*

MONTH	MONTHLY MEAN	MEAN MONTHLY HIGH	MEAN MONTHLY LOW
JANUARY	-16.4	-10.8	-21.9
FEBRUARY	-12.5	-6.3	-18.7
MARCH	-4.0	1.4	-9.4
APRIL	5.1	11.7	-1.5
MAY	10.3	17.0	3.6
JUNE	14.1	19.9	8.3
JULY	16.0	21.7	9.9
AUGUST	14.7	20.9	8.5
SEPTEMBER	10.7	17.7	3.8
OCTOBER	4.7	11	-1.9
NOVEMBER	-8.0	-3.2	-12.8
DECEMBER	-9.8	-5.8	-16.8

individual, cause of death, location of the recovered remains, clothing associated with the individual, postmortem animal activity or damage, time elapsed since individual was last seen/reported missing, degree of decomposition, body parts or skeletal elements not recovered and the method of positive identification.

In addition, further analysis was done on all cases in which the time since death was determined to be less than seven months. Comparisons with local meteorological data for the PMI provided valuable information on natural decay rates for the various seasons and demonstrated that decomposition may occur more rapidly than previously expected, despite extreme winter conditions.

2.2 METHODS

A computer search of files from the years 1990 to 1996 selected cases in which the individual was initially classified by the keyword "unidentified". A manual review of these files produced a total of 20 cases involving advanced decomposition, characterized by partial to complete skeletonization of remains. Information was recorded from the autopsy report and medical examiner's summary, as well as from photographs where available. All individuals have subsequently been positively identified.

A subset of cases ($n=10$) in which the elapsed time (the period from when the individual was last seen alive to when the body was discovered) was approximately 200 days or less was compared with data from the Environment Canada meteorological recording station nearest to the body recovery site.

2.3 RESULTS

A summary of the 20 cases is found in Table 2.2. All individuals were adult: 15 males, 5 females. The cause of death could not be determined in 10 of the cases; the remaining cases involved drowning, gunshot wounds, drug overdose and blunt cranial trauma.

TABLE 2.2 Case summary

CASE	SEX	AGE	CAUSE OF DEATH	LOCATION OF BODY	CLOTHING FOUND	PM IN MONTHS	PM ANIMAL DAMAGE	DECAY STAGE	SKELETAL ELEMENTS ABSENT	METHOD OF ID
1	M	48	undetermined	wooded area	jeans, no shirt	4	extensive rodent	skeleton, little soft tissue	Fig. 2.1, fleshed R hand found	fingerprints x-ray
2	F	28	drowning	river	bra, shorts, shoes only	3.5	none	advanced adipocere	L hand, scalp, hair, nose	dental x-ray
3	M	61	drowning	river	fully clothed	3.5	moderate fish	moderate	face defleshed	wallet w/ID
4	M	21	hypothermia/ drug OD	city park	full winter w/ coat	<2	extensive carnivore	moderate due to animals	face/nose absent due to animals	fingerprints
5	M	32	undetermined	wooded area	ski pants, socks, boots	18	extensive carnivore	skeleton, little soft tissue	Fig. 2.1	x-ray
6	M	35	undetermined	gully	overalls	1.5	extensive carnivore	advanced, no intern. organs	Fig. 2.1	dental records/x-ray
7	M	22	drowning	river	pants only	18	none	advanced, no intern. organs	Fig. 2.1 head skeletonized	x-rays, video superimpose.
8	F	26	undetermined	ravine	n/a	42	moderate carnivore	skeleton, dried soft tissue	skull only, post cranial absent	dental x-ray
9	M	31	drowning	river	full winter w/ coat	6	none	partial skeleton	L hand separate but recovered	x-ray
10	M	26	gunshot	wooded area	t-shirt, jeans, socks, shoes	5	none noted	skeleton, some soft tissue	Fig. 2.1	dental, video superimpos.

11	M	71	undetermined	farmed field	fully clothed w/ jacket	18	minor rodent	completely skeleton	L foot, R/L hand phalanges	x-rays, video superimpos.
12	M	23	undetermined	heavy wood	full winter w/ boots	16	moderate carnivore	completely skeleton	most of L hand, most of hyoid	dental records
13	F	22	blunt cranial trauma	buried	wrapped in blanket	12	none	advanced w/ soft tissue	all recovered	dental records/x-ray
14	M	40	undetermined	shallow grave	none	2	extensive bear	completely skeleton	Fig. 2.1	frontal sinus x-ray
15	M	53	gunshot	wooded area	n/a	96	moderate carnivore	completely skeleton	skull only	video superimpos.
16	M	27	undetermined	river bank	t-shirt recovered	12	moderate beaver	partial skeleton	hand bones, L leg separated	dental records
17	M	26	gunshot	wooded ravine	shirt, jacket, pants	15	extensive carnivore	completely skeleton	Fig. 2.1	x-ray, video superimpos.
18	F	19	undetermined	hillside dugout	jacket, jeans, t-shirt, boots	32	moderate rodent	advanced mummified	L hand, T8, T9, 4 ribs, sternum	dental, fingerprints
19	M	42	undetermined	river bank	none	5	moderate	skeleton	Fig. 2.1	x-rays, dental
20	F	35	homicide w/ dismemberment	river bank/ under bridge	torso in suitcase/ legs in plastic bag	6	none	advanced adipocere	all elements recovered	DNA

Two cases (1 and 20) involved dismemberment of the body prior to deposition, while a third (case 13) showed evidence of attempted dismemberment.

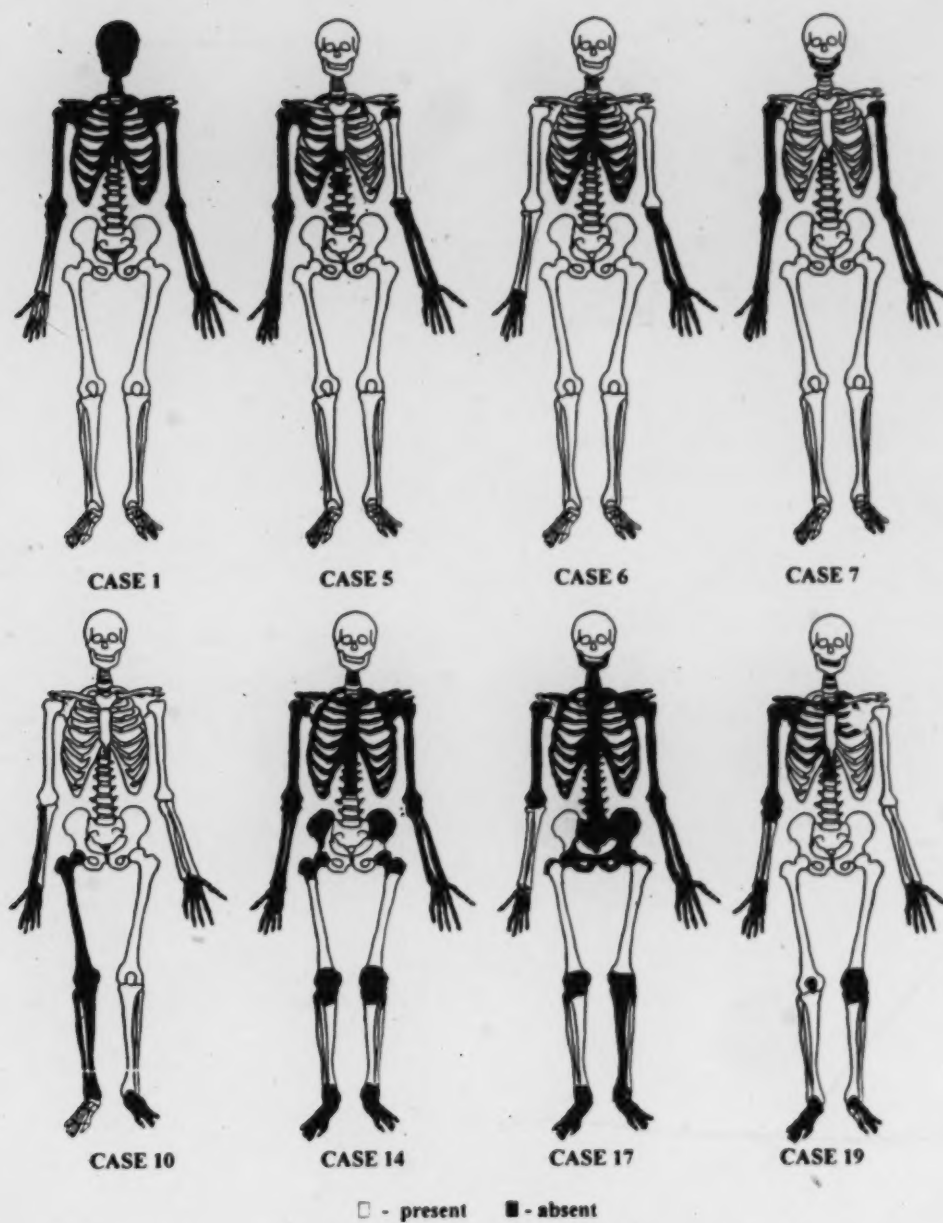
Remains were discovered in a variety of environments, with 11 cases recovered from isolated wooded areas, 4 individuals retrieved from the North Saskatchewan River, and 3 recovered on or near its banks. Two cases involved burials.

The elapsed time interval ranged from six weeks to eight years. A total of 12 cases were discovered within one year of the individual's disappearance.

At least partial clothing was recovered in 70% of the cases. Evidence of postmortem animal activity was seen in all but six cases. Animal damage was evident in one of the two cases of burial, in which bears had uncovered the shallow grave and consumed the majority of the remains.

The degree of decomposition was recorded as described in the autopsy notes, with 2 cases presenting moderate decomposition (partial exposure of bone, loss of body parts, adipocere formation); 6 cases showing advanced decomposition (loss of internal organs, moderate bone exposure, extensive adipocere); 5 cases involving partial skeletonization (complete exposure of some bony elements, only desiccated soft tissue remaining) and 7 cases with complete skeletonization (no soft tissue recovered). An inventory of the body parts/skeletal elements not recovered can be found in Table 2.2 and Figure 2.1.

Table 2.3 summarizes the ten cases involving an elapsed time interval of less than seven months.

**FIGURE 2.1**

Summary of skeletal elements absent for select cases

TABLE 2.3 Mean temperature during elapsed time for cases with time since death of <200 days.

CASE	LOCATION OF BODY	CLOTHING FOUND	ANIMAL DAMAGE	DEGREE OF DECAY	MONTHS MISSING	ELAPSED TIME (DAYS)	MEAN TEMP DURING ELAPSED TIME	MEAN HIGH DURING ELAPSED TIME	MEAN LOW DURING ELAPSED TIME
1	wooded area	jeans, no shirt	extensive	skeleton	January-April	116	-7.1 C	0.3 C	-14.5 C
2	river	bra, shorts, shoes only	none	advanced	June - October	109	13.9 C	18.5 C	9.2 C
3	river	fully clothed	moderate	moderate	February-May	108	-0.8 C	4.1 C	-5.7 C
4	frozen in park	full winter w/ coat	extensive	moderate	December-February	52	-13.7 C	-8.7 C	-18.7 C
6	gully	overalls	extensive	advanced	May-July	46	14.6 C	18.3 C	10.8 C
9	river	full winter w/ coat	none	skeleton	December-June	197	-3.1 C	3.5 C	-9.7 C
10	wooded areas	T-shirt, jeans, socks/shoes	none	skeleton	June-November	167	11.6 C	18.2 C	5.0 C
14	shallow grave	none	extensive	skeleton	June-August	45	12.2 C	20.2 C	4.3 C
19	river bank	none	moderate	skeleton	June-November	144	11.7 C	17.0 C	6.3 C
20	river bank	in plastic	none	advanced	July-February	202	-0.7 C	4.1 C	-5.5 C

2.4 DISCUSSION

Previous reports have detailed the impact of various factors on decomposition rates, including: temperature and humidity (Mann *et al.*, 1990; Vass *et al.*, 1992) aqueous versus terrestrial deposition (Haglund, 1993), burial (Mann *et al.*, 1990; Rodriguez and Bass, 1985), sun exposure (Shean *et al.*, 1993), trauma to the body (Mann *et al.*, 1990; Micozzi, 1986), insect, carnivore and rodent activity (Mann *et al.*, 1990; Rodriguez and Bass, 1983; Schoenly *et al.*, 1991), clothing, and body size (Mann *et al.*, 1990). Of these, temperature is by far the most influential (Mann *et al.*, 1990; Vass *et al.*, 1992). Decomposition rates are dramatically reduced or arrested during periods of cold or freezing (Mann *et al.*, 1990). Galloway *et al.* (1989) found that skeletonization was reached in one fifth the time in summer as compared to winter in southern Arizona.

Results demonstrate that, during the summer, reduction to skeletal remains can occur in the Edmonton region in less than six weeks. Previous reports show that in summer complete skeletonization can occur in six months in central New Mexico (Schoenly *et al.*, 1991) and southern Arizona (Galloway *et al.*, 1989), and in as little as two weeks in eastern Tennessee (Mann *et al.*, 1990) and Mississippi (Stewart, 1979).

Winter decomposition rates in this study appear slower than those of summer, with one case (Case 1) showing skeletonization in under four months with a mean PMI temperature of -7.1°C . It is important to remember, however, that skeletonization could have occurred earlier and that, unlike studies of PMI in which decay rates are observed, observations in this study relied on body recovery times and therefore may not represent the minimum amount of time needed to reach that stage of decay. Micozzi (1986, 1997)

found that animals which were frozen and then thawed disarticulated at a faster rate than fresh killed animals as a result of the mechanical disruption of tissues caused by freezing. It is possible that similar tissue disruption may explain, in part, the rapid rate of decay and disarticulation seen in remains left exposed during winter (Micozzi, 1986).

Postmortem animal activity was seen in the majority of terrestrial deposition cases. Indigenous scavengers in the central Alberta region include coyote, red fox, wolf, black bear, and porcupine (Quinn and Butler, 1987). Extensive bone dispersal and gnawing associated with domesticated dogs have been reported previously (Mann *et al.*, 1990; Wiley and Snyder, 1989) and several cases in this study showed similar patterns of canine activity. Individuals recovered from or near the river showed less animal damage, although single cases bore evidence of fish and beaver activity.

Of the ten cases seen in Table 2.3, skeletonization occurred in five. Of these, animal activity was noted to be moderate to extensive in three and absent in two. Of the five cases not associated with the river, animal damage was extensive in all but one case. Carnivores may become more aggressive during cold periods (Bass, 1997). Moderate to extensive animal activity was seen year round and appears to play an important role in the rapid decomposition rates experienced in the Edmonton area.

Entomological studies have shown a correlation between decay rates and carrion insect activity (Catts and Haskell, 1990; Rodriguez and Bass, 1983), with the majority of soft-tissue disappearance being attributed to insect larvae feeding (Mann *et al.*, 1990). Unfortunately, in this review insect activity was rarely noted in the autopsy reports and could not be reliably determined from photographs, and as such the role of insects in this

climate requires further study. Preliminary reports from entomological investigations involving pig carcasses in southwestern British Columbia have been published (Anderson and VanLaerhoven, 1996); however, meaningful comparisons with this study are not possible as results focus on summer decomposition in a far more temperate climate.

Depositional environments clearly influenced rates of decay. Bodies retrieved from the river mirrored the disarticulation sequences for aqueous environments outlined by Haglund (1993). The two burials also resembled previous reports by Rodriguez and Bass (1985), in that shallow burial resulted in rapid decay, while deeper burial resulted in greater tissue preservation despite a longer PMI.

The effects of associated clothing were similar to those reported by Haglund (1993) in that clothing retarded the disarticulation process in aqueous deposition cases and the presence of shoes retained foot and ankle bones in terrestrial and aqueous cases. Contrary to the findings of Mann *et al.* (1990), clothing did not accelerate the decay process by protecting maggots from sunlight, but rather appeared to protect underlying tissues from animals, wind, rain and sunlight which in turn retarded decay rates. In several cases, lower limb bones encased in pants retained soft tissues while the unclad upper torso was reduced to skeleton.

Animal activity, depositional environment and clothing all influenced what portions of the body were ultimately recovered. Hands and upper limb bones were rarely recovered, even for individuals experiencing only moderate to advanced decompositional changes. While skulls were often recovered, mandibles and hyoids were not. Body regions most

often recovered included the lumbar vertebrae, pelvis and lower limb bones, although bone ends were often absent due to animal gnawing.

Recovery methods may also play a role in determining how much of the body is ultimately retrieved. Investigator inexperience or bias (Haglund and Sorg, 1997) may have affected recovery rates in those cases in which trained pathologists or anthropologists were not present at the recovery scene. In addition, heavy snowfall hindered recovery of skeletal remains in at least one case, necessitating a second search of the area following the spring thaw. Such delays prolong exposure to elements and increase animal scavenging opportunities, resulting in the potential loss of skeletal elements.

2.5 CONCLUSIONS

A review of advanced decay cases from the Edmonton Medical Examiner's office revealed that decomposition to skeletal remains may occur in less than six weeks in moderate summer temperatures and in less than four months in extreme winter conditions. Accelerated decomposition rates in all seasons were often accompanied by moderate to extensive animal activity.

Based on information compiled in the review, subsequent field experimentation in the Edmonton area should take into account the following considerations: 1) the inclusion of both male and female subjects; 2) although cases involving subadults were absent, age cohorts should include subadults to control for variations due to body size; 3) experimental design must include a variety of depositional environments, particularly

wooded areas, rivers and burials; 4) unrestricted access to the decay subjects by insects and animals is necessary to reproduce natural conditions; 5) the effects of various types of clothing need to be represented; and 6) the portions of the body most likely to be recovered and therefore most appropriate as a focus of study include the lumbar vertebrae and pelvic girdle, lower limb long bones and feet, and the skull minus the mandible.

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3. HANGINGS IN ALBERTA, WITH SPECIAL REFERENCE TO OUTDOOR HANGINGS WITH DECOMPOSITION¹

3.1 INTRODUCTION

Depositional environment affects decompositional rates and sequences (Haglund, 1993; Mann *et al.*, 1990; Bell *et al.*, 1996; Rodriguez and Bass, 1985; Shean *et al.*, 1993; Galloway *et al.*, 1989). Although hanging is a well documented phenomenon (Guarner and Hanzlick, 1987; James and Silcocks, 1992; Luke *et al.*, 1985; Bowen, 1982; Jordan *et al.*, 1987; Simonsen, 1988; Saternus, 1984; Perrot *et al.*, 1985; Cooke *et al.*, 1988, 1989; Spitz, 1993; Ubelaker, 1992; Knight, 1991; Clark, 1986; Clark *et al.*, 1993; James and Nasmyth-Jones, 1992), the effects of body suspension on the decay process have not been previously examined. Prior hanging studies have purposefully excluded cases involving decayed remains (Luke *et al.*, 1985; Saternus, 1984). Decomposition can alter or obliterate evidence of perimortem trauma; Patel (1997) reports a case of indoor ligature self-strangulation in which the strangulation was initially undetected because of postmortem changes. Further interpretive challenges are encountered in those cases involving advanced stages of decomposition as a result of prolonged exposure out of doors; however, outdoor and decomposed hangings have received little attention in the literature. Haglund (1992) details one case involving a suicidal hanging recovered after 7.4 months in a secluded wooded area in which rats had constructed a nest in the thorax.

¹ A version of this chapter has been submitted for publication. Komar, D, Beattie, O, Dowling, G and Bannach, B. 1999, *Canadian Society of Forensic Science Journal*.

A review of hanging cases in the province of Alberta over an 8 year period was undertaken in order to determine the frequency, circumstances and demographic distribution of outdoor and decomposed hangings. Three cases involving outdoor hangings with advanced stages of decomposition are presented to illustrate characteristics of decay associated with hanging.

3.2 RECORDS REVIEW -METHODS

A computer search of files (January 1, 1990 through December 31, 1997) from the Office of the Chief Medical Examiner for the Province of Alberta selected cases in which the cause of death was attributed to hanging. A manual review of the identified files, which included the autopsy report and Medical Examiner's summary, and associated police reports and photographs where available, was undertaken. Information was recorded on the age, ethnic affinity and sex of the individual, manner of death, month in which the hanging took place, body location and decompositional state at recovery, type of ligature used and the elapsed time between death (when the individual was last seen alive as documented in police reports) and body recovery. In all cases involving outdoor hangings, the presence or absence of a suicide note was recorded, as well as whether the hanging occurred in a rural setting or within city limits. All individuals were positively identified.

3.3 RECORDS REVIEW - RESULTS

The computer and subsequent manual search identified a total of 478 cases of hanging. The total number of cases in any one year ranged from 39 to 72, with an average of 60 per year. The manner of death in all but 10 cases was suicide. Eight cases were ruled to be accidental, including one case of autoerotic asphyxia, while the manner of two remained undetermined (Table 3.1). There were no homicidal hangings.

In this study, males comprised 83.7% of the cases, females 16.3%. The age range of victims was 2 to 97. Accidental deaths involved children ages 2 through 11, with the exception of a 26 year old male whose death was attributed to autoerotic asphyxiation. The two undetermined deaths were juveniles, aged 10 and 12. The age range for suicides was 9 through 97, with the majority of victims (50.4%) in the 20 to 40 year categories (Table 3.1). Most individuals included were described as white (67.4%) or aboriginal (27%, Table 3.1), with a complete absence of blacks.

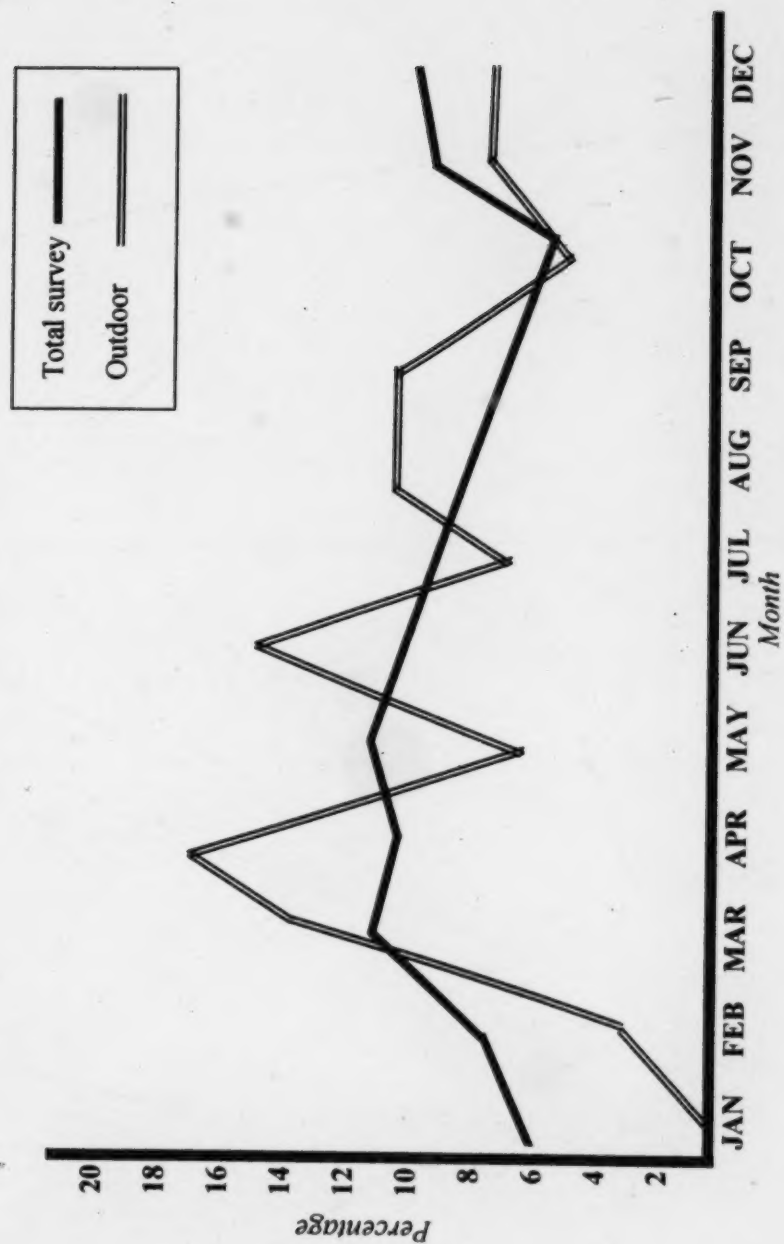
Little seasonal variation was observed in the overall survey, with the number of hangings in any month remaining fairly constant (Figure 3.1); slight declines were seen in January and October.

Ligatures used included ropes (43.1%), extension cords (23.4%), clothing and belts (30.3%), as well as isolated cases involving dogleashes, garden hoses, hammocks and coat hangers (Table 3.1).

TABLE 3.1 *Summary of case review, 1990 - 1997 (478 cases total)*

CHARACTERISTIC	# OF CASES	PERCENTAGE
MANNER OF DEATH		
Suicide	468	97.9
Accidental	8	1.7
Undetermined	2	0.4
SEX		
Males	400	83.7
Females	78	16.3
AGE AT DEATH		
< 10 years	10	2.1
11 - 20 years	86	18.0
21 - 30 years	121	25.3
31 - 40 years	120	25.1
41 - 50 years	65	13.6
51 - 60 years	34	7.1
61 - 70 years	19	4.0
71 - 80 years	11	2.3
81 - 90 years	10	2.1
> 90 years	2	0.4
ETHNIC AFFINITY		
Caucasian	321	67.1
Aboriginal	130	27.2
Asian	11	2.3
East Indian	8	1.7
Hispanic	4	0.8
Other	4	0.8
LIGATURE USED		
Rope / Clothesline	206	43.1
Extension cord / Wire	112	23.4
Clothing / Cloth	87	18.2
Belt	58	12.1
Dogleash	5	1.1
Other / Unknown	10	2.1

FIGURE 1 Survey total (478) vs. outdoor (55) hangings per month



The locations chosen are presented in Table 3.2. The majority occurred indoors (88.5%), with a dwelling's basement being most common (30%). Hangings which occurred out of doors represent 11.5% (55 cases) of the total included in this study.

TABLE 3.2 *Location of hanging.*

LOCATION	# OF CASES	% OF TOTAL CASES (478)	% OF SUBSET
INDOOR HANGINGS (Subset - 423)			
Basement	143	30.0	33.8
Barn / Shed / Garage / Outbuilding	93	19.5	22.0
Bedroom	41	8.6	9.7
Bathroom	38	7.9	9.0
In custody / Hospital	31	6.5	7.3
Closet	23	4.8	5.4
Hallway / Stairwell	22	4.6	5.2
Living Room / Dining Room	15	3.1	3.5
Hotel Room	7	1.5	1.7
Work / Industrial Building / Unknown	6	1.3	1.4
Kitchen	4	0.8	1.0
OUTDOOR HANGINGS (Subset - 55)			
Tree	30	6.3	54.5
Playground Equipment	5	1.0	9.1
Balcony / Deck	5	1.0	9.1
Post / Pole / Wooden Structure	3	0.6	5.5
Bridge	3	0.6	5.5
Truck / Vehicle	3	0.6	5.5
Other (Roof / Creek / Grain Ladder)	3	0.6	5.5
Gate / Fence	2	0.4	3.6
Window	1	0.2	1.8

Most outdoor hangings (70.9%) occurred outside of city limits, usually in rural wooded areas. Two of the 55 cases were accidental, including a child caught by

clothing on playground equipment and an autoerotic asphyxia in an isolated area. The remaining 53 cases (96.4%) were suicides. Of these, 15 (27.3%) left suicide notes. Choices for outdoor locations are summarized in Table 3.2, with a ligature suspended from a tree being most prevalent (54.5%). Outdoor hangings occurred in every month of the year except January and peaked in March, April and June (Figure 3.1).

A summary of the elapsed time between death (or the date the individual was last known to be alive) and the discovery of the body is given in Table 3.3. The majority of all cases (61%) were discovered within hours. Only 1.6% of the indoor cases had a PMI exceeding one week, while 12.7% of the outdoor cases remained undiscovered for more than one week.

TABLE 3.3 *Elapsed time, from death until body recovery.*

ELAPSED TIME	# OF CASES	PERCENTAGE
INDOOR CASES (423)		
< 1 Hour	98	23.3
< 1 Day	262	61.3
< 1 Week	56	13.3
< 1 Month	6	1.4
< 1 Year	1	0.2
OUTDOOR CASES (55)		
< 1 Hour	9	16.4
< 1 Day	34	61.8
< 1 Week	5	9.1
< 1 Month	3	5.5
< 1 Year	2	3.6
> 1 Year	2	3.6

Incidental findings from the review include the presence of a padded ligature in 11 cases of suicide. Bound hands were noted in six cases, including one using handcuffs, while the head was covered in three cases and the mouth taped shut in one. Two individuals attached additional weight to their bodies prior to the hanging event. In one instance, the victim was nude. Self-inflicted trauma prior to hanging was seen in 18 cases, including 15 with hesitation cuts of the wrists, two who shot themselves before hanging themselves and one who hung himself in a closed garage with a running car.

3.4 CASE STUDIES

Three cases with extended PMIs (5 weeks, 16 months and 10 years) and advanced states of decay were selected from the 55 outdoor cases in the records review.

Case 1

A 25 year old native male was reported missing on August 3, 1995 following the discovery of a note in his home indicating the intent to take his own life. His body was found five weeks later in a rural bush area. His fully clothed body was in a seated position under a tree suspended by a wire clothesline ligature. The body was badly decomposed and the facial features destroyed by insects. Insect activity, described in the autopsy report as "defects from maggots", was also noted in the neck area surrounding the ligature. Full natural dentition remained and dental records provided the means of positive identification. No postmortem canid or carnivore damage to the remains was noted in either the police or autopsy reports.

Case 2

The body of a 39 year old white male was discovered on May 24, 1993 hanging by an extension cord from a tree in a city ravine. Dental records were used to identify the man, who had disappeared 16 months prior. The body was fully clothed, including winter jacket, boots and jeans. The extremities were mummified and the skull and neck had skeletonized, yet full dentition and eyelashes remained (Figure 3.2). The body at recovery was in a seated position with the legs extended. Postmortem damage to the legs, attributed to carnivores, extended from the bottom of the coat to the top of the boots (Figure 3.3). Pupal casings were found in the clothing and on the body.

Case 3

On June 27, 1984, a locked car was discovered parked near a rural boat launch. A pair of men's boots had been placed carefully behind the car, and a folded set of clothing, including socks and underwear, were recovered inside the car. The car belonged to a 25 year old white male who had not been seen since leaving work a few days prior to the discovery of the car. He had a history of alcohol abuse and an inability to stay employed. Family members indicated he had been acting "strangely" prior to his disappearance, and had spoken in vague terms of taking his life. Repeated foot, air and boat searches of the surrounding land and river failed to uncover any information and he was presumed to have drowned.

On April 3, 1994, hikers discovered a human head hanging by a nylon rope (Figure 3.4) from a tree approximately 100 meters off a trail near the boat launch. The first



FIGURE 3.2

Face and neck of hanging victim described in Case 2, following a PMI of 16 months. Note rodent gnawing on upper loop of ligature, as well as retention of eyelashes and full dentition.



FIGURE 3.3

Case 2 - close up view of the legs showing postmortem animal scavenging.

four cervical vertebrae were attached to the skull as was the mummified skin of the neck, thorax, abdomen, thigh, right shoulder and arm, measuring 122 cm in length. Twenty-two postcranial bones were found scattered on the ground below, most of which showed moderate postmortem chewing by canids and rodents. A pair of handcuffs and its key were also recovered below the remains. Only one side of the cuffs were closed. The only clothing recovered were remnants of underwear- either a t-shirt or briefs.

A faded dish towel remained in place between the ligature and the neck. Several pupal casings were recovered from the towel and mummified skin. The skull was suspended approximately 10 feet (3 m) above the ground. The rope extended up, over a branch and then traveled back down and was tied to a lower branch. Beneath the suspended remains was the horizontal trunk of a second tree, running parallel to the ground at a height of 5 feet (1.5 m). The arrangement of the two trees was such that the head of a person standing on the fallen tree would have been at approximately the same height as the suspended remains (Figure 3.5).

No perimortem trauma was evident on the recovered remains. Comparisons with antemortem x-rays confirmed the remains to be those of the young man whose car had been discovered 10 years prior. The manner of death was thought to be suicide.

3.5 DISCUSSION

Comparisons of the results of this records review with previous surveys reveal several variations. Hanging as a method of suicide is more prevalent among males



FIGURE 3.4

Case 3 - close up view of suspended skull, following a PMI of 10 years. Note the padded ligature and full dentition.



FIGURE 3.5

Case 3 - general view of death scene. Arrow indicates suspended remains.

(Guarner and Hanzlick, 1987; James and Silcocks, 1992; Luke *et al.*, 1985; Bowen, 1982), and men accounted for over 80% of the cases in this study. The percentage of females represented (16.3%) was higher than the 7.3% reported from Cardiff (James and Silcocks, 1992) and the 10% reported from Georgia (Guarner and Hanzlick, 1987), but was consistent with values reported for London (Bowen, 1982) and Seattle (Luke *et al.*, 1985). Despite having been reported previously (Lew, 1988; Vieira *et al.*, 1988; Leth and Vesterby, 1997), no homicidal hangings were identified in the survey.

While the majority of previous review studies (James and Silcocks, 1992; Luke *et al.*, 1985; Bowen, 1982; Simonsen, 1988; Saternus, 1984) do not specify location, this study indicates that outdoor hangings are not infrequent in Alberta at 11.5%, higher than the 9% reported in Georgia (Guarner and Hanzlick, 1987). Although aboriginal peoples represented only 27% of total hangings, they accounted for 58.2% of the outdoor hangings, suggesting a cultural bias not only in suicide method but also in location. Of the 53 cases involving outdoor suicidal hangings, 15 (27.3%) left suicide notes. This was higher than one previous report of 18% for all forms of hangings (Guarner and Hanzlick, 1987), but considerably lower than the 36.1% cited in another study (Luke *et al.*, 1985).

A unique feature of this study is the inclusion of data regarding the length of time between death and body recovery (PMI). Results of this survey indicate that there is a similarity in the length of time between death and body recovery for both indoor and

outdoor hangings, though outdoor cases (due to remote locations or more easily obscured scenes) resulted in a small number of victims remaining undiscovered for longer periods of time. Prolonged PMI can confound scene analysis and decomposition change can modify or destroy the medical evidence (Patel, 1997).

Comparisons of the three case studies with a previous study (Komar, 1998) of terrestrial cases (surface depositions and shallow burials) from the same region and time period (1990-1996) suggest that decomposition rates are significantly slower in the case studies involving partial to full suspension of the body. As a result, mummification of soft tissues and skin appears to be more common and extensive in the hanging cases. Finally, postmortem tooth loss due to decomposition, scavenging, and dispersal or movement of remains by animals is a common feature of surface depositions (Haglund, 1997). However, retention of full natural dentition *in situ* (see Figures 3.2 and 3.4) is evident in all three case studies. This may be the result of continued articulation between the skull and mandible due to slow decomposition as well as the protection from animal scavengers afforded the head and upper torso by suspension. Haglund (1997) reports a case involving a decomposed hanging recovered in a wooded area after a PMI of 45 months in which 14 teeth were absent postmortem. The skull and mandible in that case were recovered from the ground beneath the noose and were described as completely disarticulated with no soft tissue present (Haglund, 1997).

Accidental deaths associated with the practice of autoerotic asphyxia have been well-documented (Spitz, 1993; Knight, 1991; Hazelwood *et al.*, 1983; Byard and

Bramwell, 1991; Emson, 1983; Boglioli *et al.*, 1991; Uva, 1995; Hiss *et al.*, 1985; Byard *et al.*, 1990; Garza-Leal and Landron, 1991). Characteristic features include: padding between the ligature and neck (Knight, 1991; Byard *et al.*, 1990; Garza-Leal and Landron, 1991; Wesselius and Bally, 1983); binding of the hands (Wesselius and Bally, 1983), often with handcuffs (Knight, 1991; Byard *et al.*, 1990); the presence of a fail-safe or rescue mechanism (Knight, 1991; Byard and Bramwell, 1991; Hiss *et al.*, 1985; Garza-Leal and Landron, 1991); an isolated location (Byard and Bramwell, 1991; Garza-Leal and Landron, 1991), often outdoors (Emson, 1983; Hiss *et al.*, 1985; Byard *et al.*, 1990); partial to total nudity (Hiss *et al.*, 1985; Garza-Leal, 1991; Wesselius and Bally, 1983) or transvestitism (Byard *et al.*, 1990); shackling or binding of the penis (Knight, 1991; Byard *et al.*, 1990); the presence of pornography (Emson, 1983; Byard *et al.*, 1990); and the absence of a suicide note or suicidal ideation (Knight, 1991; Byard and Bramwell, 1991; Byard *et al.*, 1990). Although most cases of autoerotic asphyxia display these features, all need not be present to satisfy the criteria (Byard *et al.*, 1990).

Autoerotic fatalities share many common characteristics with homicides and suicides (Garza-Leal and Landron, 1991). Features normally associated with sexual asphyxia also occur in isolation or in combination in cases of true suicide. Examples of padded ligatures, handbinding (including the use of handcuffs), and nudity were noted in this study. The absence of a suicide note is also not conclusive, as evidenced in the current and previous studies (Guarner and Hanzlick, 1987; Luke *et al.*, 1985).

Case study 3 presents many of the diagnostic features of autoerotic asphyxia: the isolated, outdoor location, the padded ligature, the partial nudity, the absence of the suicide note and the presence of the handcuffs. Absent is any evidence of cross-dressing or pornography, although after 10 years items such as paper and clothing may have disintegrated or been removed by animals. Initial scene analysis was consistent with a potential autoerotic death.

Interviews with the victim's family members revealed a history of depression and past suicidal ideation. A further important factor was the absence of any fail-safe mechanism. The ligature was a simple slip-knot, suspended at a height of 10 ft (3 m), allowing no control by the victim over the degree of constriction. Also, it is not uncommon for suicidal individuals to bind their wrists in a hanging (as seen in 6 cases in this study), in order to ensure they "don't change their minds". Consideration of this evidence led to the final ruling of suicide.

Scene analysis alone is insufficient and initial impressions often prove incorrect. In a previous report of an autoerotic asphyxial death initially misinterpreted as a suicide (Garza-Leal and Landron, 1991), scene interpretation was complicated by the altering of evidence at the scene by a family member. Extended PMI, exposure to the elements, and the actions of animals may also confound scene analysis. In cases of equivocal death, rulings should be not be rendered until all relevant details are available for both the scene and the victim's history (Hazelwood *et al.*, 1983).

3.6 CONCLUSIONS

This study demonstrates that outdoor hangings are not infrequent, that they can result in greater time to discovery and as a result, interpretation of the scene and remains maybe hampered by postmortem changes. Like water or burials, hangings represent a unique depositional environment. Standards or methods of analysis generated from terrestrial models should be used with caution in cases involving partial to full suspension of the body. Further research in this area is warranted.

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4. EFFECTS OF CARCASS SIZE ON DECAY RATES OF SHADE AND SUN EXPOSED CARRION¹

4.1 INTRODUCTION

During decomposition, a body undergoes an extensive series of biochemical and morphological changes as it decays from a fresh to skeletal state (Anderson and VanLaerhoven, 1996). Understanding and recognizing the timing and sequence of these changes is paramount in making an accurate estimation of the elapsed time since death in forensic investigations. Given the ethical and moral considerations and the difficulties in obtaining human cadavers for use in these types of experiments (Schoenly *et al.*, 1991), many investigators, most notably entomologists, have turned to animal models to study decomposition.

Domestic pigs (*Sus scrofa*) have been used extensively as models for human decomposition as they have relatively hairless skin similar to humans and are omnivorous with equivalent digestive tract fauna (Anderson and VanLaerhoven, 1996). Although small pigs, including stillborn neonates (Payne *et al.*, 1968) and carcasses as small as 8.4 kg (Hewadikaram and Goff, 1991) have been used, 22 to 23 kilogram pigs have been recommended (Catts and Goff, 1992) and used (Anderson and VanLaerhoven, 1996) as appropriate models for humans as the carcass size is equivalent to an adult male torso, the area where decomposition is centered (Anderson and VanLaerhoven, 1996).

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However, carcass size may impact decomposition rates (Anderson and VanLaerhoven, 1996). Denno and Cothran (1975) found differences in the species and proportions of necrophagous flies on various types of carrion, including rat, rabbit and sheep. Hewadikaram and Goff (1991) found no size-related differences evident in insect species composition or patterns of succession, although an increase in insect number on a larger carcass resulted in a more rapid loss of biomass when compared to a smaller carcass, thereby affecting overall decomposition rates.

To determine the impact of carcass size on decay rates, 14 pig carcasses, ranging in size from 19 to 162 kg, were decomposed in a variety of depositional environments at a research facility near Edmonton, Alberta. Comparisons with estimated rates of human decomposition for that region, taken from the records of the Office of the Chief Medical Examiner for Alberta Justice (Komar, 1998), may suggest whether the recommended carcass size best approximates humans for the Edmonton area.

4.2 METHODS

A low-traffic area of the Hasse Lake Provincial Park, closed to the public, was selected as the research site. The park is located 50 km west of Edmonton and is comprised of boreal forest and pasture. Although authorization for use of the land had been granted, a public complaint resulted in the cancellation of the permit and termination of the project after 25 days. A two week extension was granted so that sufficient data could be collected prior to final disposal of the carcasses.

Recently deceased pigs were obtained from a local processing plant and a meat packaging facility; no animals were killed specifically for this experiment. Exact times of death were known for each animal. All pigs were weighed at the plants prior to their deposition. As clothing has been shown to affect decomposition rates (Mann *et al.*, 1990) and insect activity (Dillon, 1997), the pigs were fully clothed, including undergarments, socks or hose and shoes.

The experiment was conducted in two phases: Phase 1 consisted of six pigs (Pig ID # 1, 4-6, 13 and 14, Table 4.1) which were placed on June 12, 1997 and Phase 2 included eight pigs (Pig ID # 2, 3, 7-12, Table 4.1) set out on June 25 and 27, 1997. Included in Phase 2 were two pairs of pigs deposited side by side and dressed identically for direct size comparison. The first pair (ID # 2, 21 kg and #12, 80 kg) were placed on the surface in open pasture, exposed to full sunlight throughout the day. The second pair (ID # 3, 21 kg and ID #4, 80 kg, see Figure 4.1) were placed on the surface in a partially shaded area which received direct sunlight from 3:00 to 8:00 p.m. daily. It should be noted that although a previous entomological study utilized close proximity of decay subjects in human decomposition experiments, this carcass arrangement raises the possibility of cross-contamination between subjects.

The carcasses were observed and photographed every day from June 12 to July 21, 1997. Body and maggot mass temperatures were recorded daily. Ambient air temperature was recorded hourly with a datalogger and rain fall was measured by several rain gauges placed on site. Final weights were determined using a mounted butchers scale on site.

TABLE 4.1 Summary of Hasse Lake specimens and time spent in each of 5 stages of decomposition.

ID #	INITIAL WEIGHT (kg)	ENVIRONMENT OF DEPOSITION	TOTAL # OF DAYS	# DAYS FRESH	# DAYS BLOAT	# DAYS ACTIVE DECAY	# DAYS ADVANCE DECAY	# DAYS TO DRY REMAINS	# DAYS TO 1st INSTAR MAGGOTS	FINAL WEIGHT (kg)	TOTAL % BIOMASS LOST
1	19	full sun/open pit	40	2	4	5	2	13	6	2.1	89
2	21	full sun/surface	27	3	7	2	3	15	5	2.3	89
3	21	partial shade/surface	27	1	10	6	2	19	8	2.7	87
4	26	shade/partial burial	40	2	11	10	2	25	8	3.6	86
5	26	shade/surface	40	1	22	8	5	36	15	3.2	88
6	36	shade/surface	40	3	14	16	7+	---	12	10.5	71
7	59	shade/surface	25	4	8	10	3+	---	6	18.6	68
8	80	shade/surface	27	3	12	7	5+	---	8	18.6	77
9	80	partial shade/surface	27	2	16	9+	---	---	10	30.5	62
10	80	full sun/surface	27	1	10	8	8+	---	5	23.6	70
11	80	full sun/surface	27	3	8	4	12+	---	4	15.0	81
12	80	full sun/surface	27	2	10	7	8+	---	4	21.4	73
13	156	full sun/open pit	40	2	7	10	21+	---	5	36.0	77
14	162	shade/surface	40	3	12	7	18+	---	5	54.0	66



FIGURE 4.1 *Partial shade pair #3(21 kg) and #9 (80 kg) on Day 1.*

Decompositional stage scoring in this study followed a five stage protocol, modified from Anderson and VanLaerhoven (1996), concentrating on the physical indicators of decay and general insect activity.

1. *Fresh*

The period from the actual time of death until the first signs of bloating are observed. This stage is characterized by a decrease in body temperature over time, no odor and the arrival of blow flies and the subsequent deposition of eggs.

2. *Bloat*

A bloated appearance, with distended abdomen caused by gas accumulation in the carcass, marks the beginning of this stage. Other signs include discoloration and marbling, strong odor, an extruded anus and a decrease in body mass. The bloated stage terminates with the collapse of the body.

3. *Active decay*

This stage begins with the collapse of the thorax as a result of maggot feeding and is characterized by the presence of sizable maggot masses. The carcass has a greasy appearance and strong odor.

4. *Advanced decay*

Diagnostic features of this stage include the disappearance of the maggot masses (although isolated maggots remain, often under skin or clothing) and a marked decrease in overall body weight, with primarily mummified skin and putty-like flesh remaining.

5. *Dry remains*

Only the bone, cartilage and mummified skin of the carcass remain. No odor is detectable and there is a complete absence of maggots.

As this study focused on factors affecting overall decay rates and was not an entomological survey, the objective was not to catalogue or identify specific species of insects. Maggot, as it is used in this survey, refers to the larval stage of Calliphoridae or blow flies, which have previously been shown to be a major consumer of pig carrion (Anderson and VanLaerhoven, 1996; Dillon, 1997; Shean *et al.*, 1993) and human corpses (Rodriguez and Bass, 1983; Haskell *et al.*, 1997).

4.3 RESULTS

All carcasses with an initial weight of 27 kg or less reached the dried remains stage within 13 to 36 days. (Table 4.1). None of the carcasses with an initial weight greater than 27 kg reached dry remains; eight of the larger carcasses had reached the stage of advanced decay while one carcass (ID #9) was still in active decay with large maggot masses after 27 days.

All specimens, regardless of size or environment, spent between one and four days in the fresh stage and no size or environment related patterns are evident in the bloat or active decay stages. A discernible difference is seen between the small and large carcasses in the number of days spent in advanced decay, with the larger carcasses remaining in the advanced decay stage for a much longer period. A summary of the time spent in each decompositional stage, along with a comparison of a previous study (Anderson and VanLaerhoven, 1996), is found in Table 4.2.

TABLE 4.2

Comparison of days after death spent in each of the five stages of decomposition between the current study in Alberta and Anderson and VanLaerhoven (1996) in British Columbia

Decomposition stage	BC Study (22 kg pigs) Days after death	Current Study (19-36 kg pigs) Days after death	Current Study (36-80 kg pigs) Days after death	Current Study (156-162 kg pigs) Days after death
Fresh	0 - 1	1 - 3	1 - 4	2 - 3
Bloat	2 - 10	2 - 23	2 - 18	3 - 15
Active	11 - 16	7 - 31	12 - 33	10 - 22
Advanced	17 - 42	12 - 35	16 - 40+	20 - 40+
Dry Remains	43+	13 - 36	—	—

Total weight loss for the smaller pigs which reached the dry remains stage ranged from 86 to 89%, while the larger carcasses in the active or advanced decay stages had lost between 62 and 81% of their initial body weight (Table 4.1).

Depositional environment played an important role in the timing of insect colonization of the carcasses, with sun-exposed pigs experiencing the onset of maggot activity in 4 to 6 days while 1st instar maggots were first observed on the shaded carcasses within 5 to 15 days (Table 4.1). Size-related differences in maggot activity were seen in the Phase 1 pigs. Of the initial six carcasses placed, the two largest (156 kg in sun and 162 kg in shade) developed maggot masses after 5 days while the four smaller carcasses were colonized after 6 to 15 days. Adult fly and maggot activity were noticeably greater on the medium and larger carcasses in both phases of the experiment throughout the first three stages of decomposition.

Comparison of the two pairs of carcasses placed side by side reveals that in the full sun pair egg deposits and 1st instar maggots appeared first on the larger pig, followed a day later on the smaller pig. In contrast, the partial shade pair saw the onset of 1st

instar maggot activity on the smaller pig first at 8 days and the larger pig at 10 days, despite egg deposits on both pigs within two days. In both pairs, the smaller pigs decayed rapidly to dry remains (Figure 4.2) while the larger pigs reached only the stages of advanced decay in the sun and active decay in the shade.

In all size ranges and environments, there was considerable variation in the rates at which eggs were deposited and hatched. This variation appears to be reflective of the often highly variable weather conditions experienced at the site during the study's duration. Heavy rains immediately following carcass deposition and near-freezing nighttime temperatures as late as June 30 appear to have had considerable effect on larvae development. A summary of the climatic conditions for the experimental period is given in Table 4.3.

4.4 DISCUSSION

Regardless of the depositional environment, the smaller size pigs (19-26 kg range) decomposed to skeletal remains at significantly faster rates than did the medium sized (36-80 kg range) or large sized (156-162 kg) carcasses. Consistent with previous findings (Shean *et al.*, 1993), full shade, partial shade and shallow burial delayed the onset of insect colonization and therefore retarded overall decay rates in the non-sun exposed carrion; however, carcass size appears to be a more influential factor.

A previous study on the effects of carcass size by Hewadikaram and Goff (1991) reports that although the rate of decomposition (as measured by percentage of carcass remaining) was more rapid in the larger carcass, the smaller carcass reached its final

TABLE 4.3 *Ambient air temperature recorded by datalogger at Hasse Lake in degrees Celcius and total daily rainfall (mm).*

DATE	DAILY HIGH	DAILY LOW	DAILY MEAN	RAIN (mm)
06/12/97	26.0	---	---	trace
06/13/97	17.0	---	---	30
06/14/97	29.1	---	---	trace
06/15/97	28.0	---	---	---
06/16/97	24.0	---	---	4
06/17/97	30.0	---	---	4
06/18/97	21.0	---	---	4
06/19/97	17.0	---	---	trace
06/20/97	13.5	10.0	11.6	14
06/21/97	17.7	9.7	11.7	35
06/22/97	13.2	7.1	9.3	42
06/23/97	16.7	5.1	10.1	30
06/24/97	26.0	7.1	14.2	10
06/25/97	28.5	5.5	15.9	---
06/26/97	23.8	6.0	12.7	trace
06/27/97	27.1	2.3	13.1	10
06/28/97	21.0	5.0	10.5	4
06/29/97	16.1	2.1	8.1	---
06/30/97	18.0	2.6	10.9	---
07/01/97	21.1	6.8	13.6	---
07/02/97	22.8	4.4	14.5	---
07/03/97	27.7	6.0	16.0	---
07/04/97	29.3	7.0	17.8	---
07/05/97	27.0	5.7	17.7	---
07/06/97	25.0	10.2	17.1	---
07/07/97	26.8	6.6	18.0	---
07/08/97	26.8	8.5	18.0	---
07/09/97	26.5	9.6	19.1	---
07/10/97	17.7	8.9	13.4	trace
07/11/97	17.3	8.6	11.5	25
07/12/97	19.5	8.9	12.6	4
07/13/97	26.6	10.8	20.4	25
07/14/97	30.7	8.7	18.6	---
07/15/97	29.0	9.1	18.5	---
07/16/97	27.0	9.1	17.1	8
07/17/97	21.2	6.1	13.3	trace
07/18/97	27.1	11.6	18.2	30
07/19/97	28.7	7.4	17.5	---
07/20/97	29.1	8.1	---	---
07/21/97	28.7	---	---	---



FIGURE 4.2 *Partial shade pair #3 (21 kg) and #9 (80 kg) on Day 15.*

stable weight (dry remains) much sooner. Direct comparison with the present study must be made with caution, as the Hewadikaram and Goff study was conducted in Hawaii, using two undressed pigs of very small size (8.4 and 15.1 kg). Carcass size pattern variations are also investigated by Denno and Cothran (1975) in California using rat, rabbit and sheep. This study does report species variability based on carcass size but also found that the successional patterns remained consistent (Denno and Cothran, 1975).

A study in the Vancouver, British Columbia area (Anderson and VanLaerhoven, 1996) using seven 22 kg unclothed pigs in full sunlight reports dramatically different time frames for each of the five stages of decay (Table 4.2) and gives a minimum of 43 days to dry remains. Most significant are the prolonged periods of bloat and active decay seen in the current study, variations which may be attributable to environmental differences and clothing, as well as carcass size. Carcass size does appear to be the primary factor affecting the significant differences seen in the amount of time spent in advanced decay between the small and larger sized carcasses (Table 4.1).

Anderson and VanLaerhoven (1996) report that data gathered from the 22 kg pig models relate well to human cases with known time of death from the Vancouver area. A case review at Edmonton's Office of the Chief Medical Examiner from 1990 to 1996 provided 20 cases involving advanced decomposition, with partial to complete skeletonization of remains (Komar, 1998). Results indicate that skeletonization can occur in as little as six weeks in summer and four months in winter, however, these

extremes were seen only in cases involving extensive postmortem carnivore activity, primarily by bears and canids. Summer time skeletonization rates in the absence of carnivore activity were four to six months (Komar, 1998).

Evidence of canids in the research facility was plentiful, including repeated sightings of coyote and fox and fresh tracks and scat throughout the site. Domestic dogs, accompanying hikers or wandering from neighboring farms, were also present. Although the carcasses were unprotected from scavengers, only three instances of minor canid scavenging were observed in the present study. These were confined to the chewing and movement of clothing and foot bones and did not produce the accelerated decomposition rates associated with extensive carnivore scavenging. Therefore, the observed decay rates of two to five weeks seen in the smaller pigs (19 to 26 kg range) appear too rapid when compared with the minimum estimated summer time human decay rate of six week (in cases involving extensive scavenging) and fall well outside the four to six month range seen in comparable cases without scavenging.

Results of this study also have implications in the determination of time since death in human remains. Similar discrepancies in decay rates may be seen between infants and adults or between adults of varying weights. This is consistent with unpublished data by Haskell (described in Catts and Goff, 1992) which report that a human infant was reduced to skeletal remains in five days while an adult human and a pig model required 15 to 25 days. Reports from the Anthropological Research Facility (ARF) in Tennessee state that obese individuals lost body mass rapidly because of the liquefaction of fat (Mann *et al.*, 1990), which is similar to the rapid biomass loss seen

in the larger carcasses of the current study. Decay rates to dry remains reported from ARF are contrary to those seen here. Results of ARF experiments show that a 119 kg female was skeletonized in two weeks while a smaller male (exact body size not reported) required twice as long (Mann *et al.*, 1990). However, details of important variables such as depositional environments, associated clothing, and the condition of the bodies are not given and an accurate comparison of results with the current study is not possible.

4.5 CONCLUSIONS

The results of the present study suggest that the recommended carcass size of 22 kg, currently used in entomological studies, decays much more rapidly than larger carcasses during the summer months in the central Alberta region, regardless of depositional environment. Comparisons with known human rates of decomposition indicate that 20 to 25 kg pigs are not an appropriate model for human decomposition for this region. Additional tests will be needed to determine which carcass size range best approximates humans for this climatic zone.

Results also suggest caution in estimating time since death in human remains. Significantly different decay rates may be expected between juveniles and adults or emaciated and overweight adults.

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5. POSTMORTEM INSECT ACTIVITY MAY MIMIC PERIMORTEM SEXUAL ASSAULT CLOTHING PATTERNS¹

5.1 INTRODUCTION

The investigation and prosecution of few crimes rely as heavily on physical evidence as does the crime of sexual assault (Fisher, 1987). Cases of sexual homicide are often difficult to solve because of a lack of this physical evidence (Ressler *et al.*, 1988), a problem which increases with delayed recovery of the body. Advanced decomposition of the victim complicates crime scene interpretation and can lead to inaccurate conclusions (Patel, 1997).

In sexual assault cases involving advanced decomposition, the physiological indicators of the assault such as the presence of semen and bruising (Moreau and Bigbee, 1995a) have disappeared and the identification of the sexual nature of the attack is dependent on crime scene interpretation. A primary indicator of sexual homicide is the state of the victim's attire or lack of attire (Ressler *et al.*, 1988; Horgan, 1979). Ripped or soiled clothing and torn-off buttons are characteristic signs of a struggle (Fisher, 1987). Patterns of disturbed clothing on the victim, allowing exposure of the breasts and genitals, suggest the sexual nature of the crime (Ressler *et al.*, 1988). These clothing patterns, termed "sexual disarray" (Ressler *et al.*, 1988), may be the only physical evidence of the assault remaining in cases involving decomposed or skeletal remains.

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Interpretation of such evidence can be complicated by natural postmortem taphonomic processes, such as the alteration of the scene and evidence by carnivore scavenging (Haglund, 1997). Insect activity has also been shown to modify the crime scene during the postmortem interval (Haskell *et al.*, 1997). Maggot masses are capable of transporting sizable objects such as dentures and bones considerable distances as well as producing postmortem artifacts which mimic perimortem trauma to soft tissues (Haskell *et al.*, 1997).

Preliminary results from two separate field experiments using clothed pig carrion (*Sus scrofa*) as a model for human decomposition suggest that postmortem insect activity frequently reproduces the sexual disarray clothing patterns seen in cases of sexual assault and sexual homicide.

5.2 MATERIALS

Fourteen pigs, ranging in size from 19 kg to 162 kg, were allowed to decompose at a research facility located 50 km west of Edmonton, Alberta (site 1). An additional six pigs, all 80 kg each, were decayed at a biological research station located within Edmonton city limits (site 2). Depositional environments included full sun, partial shade or full shade exposure as well as surface, open pit and partial burial depositions throughout the boreal forest and pasture research facilities (Table 5.1). Prior to deposition, all carcasses were dressed in adult-size clothing, complete with undergarments, socks or hose and shoes (Figure 5.1). Carcasses were monitored daily, including the recording of ambient, body and maggot masses temperatures.

TABLE 5.1 Summary of carrion environment, clothing and postmortem clothing changes.

ID #	INITIAL WEIGHT (kg)	DEPOSITIONAL ENVIRONMENT	CLOTHING	BUTTONS/ SEAMS TORN	UPPER CLOTHING DISPLACED	LOWER CLOTHING DISPLACED	UNDER- GARMENTS DISPLACED	SOCKS/ STOCKINGS REMOVED
SITE 1								
SFS-2	19	full sun/open pit	sweater/shorts					N/A
SFS-5	21	full sun/surface	shirt/underwear/socks				X	
SS-5	21	partial shade/surface	t-shirt/underwear/socks					
PRED1	26	shade/partial burial	dress/jacket/bra/slip/hose		X			
PRED2	26	shade/surface	dress/underwear/bra/hose					
SS-1	36	shade/surface	pants/shirt/socks/underwear		X			
SS-6	59	shade/surface	dress/underwear/hose	X				
SS-3	80	shade/surface	shirt/skirt/hose/underwear	X		X		
SS-4	80	partial shade/surface	t-shirt/underwear/socks		X	X		
SFS-3	80	full sun/surface	skirt/shirt/underwear/hose	X	X			X
SFS-4	80	full sun/surface	shirt/jacket/pants/boxers/socks		X	X		X
SFS-6	80	full sun/surface	shirt/underwear/socks		X	X		X
SFS-1	156	full sun/open pit	shirt/pants	X	X			
SS-2	162	shade/surface	dress/bra/boxers/hose	X	X			N/A
SITE 2								
GFS-1	80	full sun/surface	t-shirt/skirt/jacket/socks			X		X
GFS-2	80	full sun/surface	shirt/pants/scarf	X	X		N/A	
GFS-3	80	full sun/surface	sweater/jacket/pants	X	X		N/A	
GSH-1	80	shade/surface	jeans/t-shirt/jacket/socks	X	X		N/A	
GSH-2	80	shade/surface	t-shirt/jacket/skirt/hose	X	X		N/A	
GSH-3	80	shade/surface	dress/tights	X	X		N/A	

Observations were made with minimal handling of the carcasses and care was taken not to disturb the clothing. A photographic record was maintained throughout the experiment, which ran a total of 40 days (June and July, 1997) at site 1 and 90 days (August to October, 1997) at site 2.

The site 1 carcasses were initially protected from carnivore and rodent scavenging by wire mesh and cages. Control pigs, set out with no protection, showed no signs of scavenging during the first phase of the experiment and the protective cages were removed from all specimens early in the study.

Decompositional stage scoring followed a five stage protocol, adapted from Anderson and VanLaerhoven (1996):

Fresh - From the time of death until the first signs of bloating are seen. A decrease in body temperature, no odor and the arrival of blow flies and the subsequent depositing of eggs characterize this stage.

Bloat - Distention of the abdomen caused by gas accumulation in the carcass marks the onset of the stage. Other signs include discoloration and marbling, strong odor, an extruded anus and a decrease in body mass.

Active Decay - Begins with the collapse of the thorax as a result of feeding by sizable maggot masses. The carcass is greasy and has a strong odor.

Advanced Decay - Follows the disappearance of the maggot masses and features a marked decrease in overall body mass. Primarily mummified skin and putty-like flesh remain.

Dry Remains - Only bone, cartilage and mummified skin remain. No odor is detectable and maggots are completely absent.

5.3 OBSERVATIONS

Insect activity generated substantial clothing changes, primarily during the bloated and active decay stages of decomposition. Maggot masses were observed shifting the position of clothes several centimeters over a period of minutes. Arrangement of the clothing on the carcasses changed daily from the onset of the first maggot masses (3 to 15 days postmortem) through to the advanced decay stage (11 + days postmortem), at which time maggots were no longer observed on the carcasses.

One important observation was the ability of the maggot mass to move clothing located on the underside of the body, despite the weight of the body overlying it and direct contact with the ground. The result, seen in the advanced decay and dry remains stages, was typically the bunching of clothes around the neck (Figure 5.3) and distal hindlimbs (Figure 5.4) in which the level of clothing is identical on both the upper and lower surfaces of the body. Of the carcasses dressed in skirts, the underwear and hose were removed down to the distal hindlimbs while the skirt was pushed up toward the thorax. Carcasses dressed in underwear and pants had both stripped down to a level equivalent to the ankles in humans (Figure 5.2).



FIGURE 5.1

An 80 kg pig (SFS-6, larger animal at top of photograph)), hours after death, clothed and placed in full sun.



FIGURE 5.2

The same carcass (SFS-6), photographed 17 days post-mortem. All clothing changes are the result of maggot activity only.



FIGURE 5.3

156 kg specimen (SFS-1), surface deposited in full sun, seen 22 days postmortem. Note the uniform displacement of shirt towards the head on upper and lower surfaces of the carcass.



FIGURE 5.4

A close-up view of the distal hindlimbs of SFS-6, taken 13 days postmortem. Maggot masses (upper left-hand corner) were observed displacing the underwear distally along the hindlimbs.

Maggots in mass also completely removed articles of clothing, particularly snug-fitting articles such as socks, hose, shoes and underwear, and in one instance removed a sock from a hindlimb and transported it 35 cm from the body.

Carcass size was an important variable in the frequency and type of clothing changes observed. Carcasses 26 kg or smaller experienced only two instances of postmortem clothing displacement (Table 5.1); all carcasses in this weight range reached the dry remains stage within the course of the experiment. All carcasses approximating human size (59 kg to 162 kg) experienced extensive clothing disarray; all but one of these carcasses had reached the advanced decay stage.

No significant differences in the degree of clothing displacement were observed between sun and shade exposed carcasses, although variations in the onset and timing of changes were noted. As direct sunlight stimulates maggot activity (Shean et al, 1993), masses developed 1 to 8 days earlier in the sun-exposed carcasses. Clothing changes were therefore seen earlier in the sun exposed pigs at both sites.

Natural decay processes produced additional clothing changes. The bloating of the thorax caused the bursting of seams and the tearing-off of buttons in snug fitting shirts made of tightly-woven, non-stretch fabrics. Discoloration of clothing began during the second week postmortem and was primarily the result of the seepage of fluid from the carcasses, in addition to slight rain and soil staining.

5.4 DISCUSSION

The use of domestic pigs as models for humans in decomposition experiments is well established (Anderson and VanLaerhoven, 1996; Shean *et al.*, 1993; Schoenly *et al.*, 1991; Haskell *et al.*, 1990; Hewadikaram and Goff, 1991; Dillon, 1997; VanLaerhoven, 1997). They are considered by some to be the best available model for humans because of their equivalent thoracic cavity size (Schoenly *et al.*, 1991), relatively hairless skin, and omnivorous diet with similar gut fauna (Anderson and VanLaerhoven, 1996). Carcass sizes of 22 to 23 kg have been recommended (Catts and Goff, 1992) and used (Anderson and VanLaerhoven, 1996; Dillon, 1997; VanLaerhoven, 1997) because this size approximates an adult male human torso.

The clothing-related findings of this study may not have been observed in previous pig carrion studies because the majority utilized unclothed specimens (Anderson and VanLaerhoven, 1996; Shean *et al.*, 1993; Hewadikaram and Goff, 1991), small carcasses sizes (under 27 kg) (Dillon, 1997; VanLaerhoven, 1997), or carnivore protection which may have restricted clothing movement. A previous entomological/decomposition experiment involving humans utilized undressed cadavers (Rodriguez and Bass, 1983).

The variations in frequency seen relating to carcass size may be explained, in part, by the better fit of the clothes to the larger sized pigs. Only adult size clothing was used and the clothes were often loose and ill-fitting on the smaller size carcasses (under 26 kg), allowing ample room for the maggot masses to maneuver beneath. However, loose fit alone does not fully explain the discrepancy between the small and

large sized carcasses. Unbuttoned, baggy shirts on large carcasses were displaced by maggots (Figure 5.2 and Figure 5.5), while snug fitting undergarments and socks on smaller carcasses did not change position throughout the course of the experiment. Larger carcasses attract greater numbers of arthropods and support larger maggot masses than do smaller carcasses (Hewadikaram and Goff, 1991). This increased activity and mass size may explain the greater degree of clothing displacement observed on the larger carcasses.

Differential interpretation of the postmortem clothing patterns produced by insects from that of carnivores or the perimortem activity of humans requires careful observation of the victim's remains and clothing as well as that of the immediate surrounding area.

5.4.1. Discerning insect versus carnivore clothing artifacts

Carnivores are capable of dramatically altering human remains, the crime scene and associated evidence including clothing during the postmortem interval (Haglund, 1997). Scavenging of soft tissues and the disarticulation and scattering of remains by carnivores may result in clothing patterns which superficially resemble those created by insect activity. Carnivores initially attack exposed parts of the body (Rossi *et al.*, 1994), and heavy clothing deters carnivore scavenging (Haglund, 1997). Indicators of carnivore interference include the presence of characteristic canine tooth puncture marks on bone, soft tissue or clothing (Haglund, 1997), extensive disarticulation or scattering of



FIGURE 5.5

A close-up view of the thorax and cranium of SFS-6, photographed 13 days postmortem. Following the removal of the protective carnivore screening (upper right hand corner), the maggot mass visible along the edge of the clothing shifted the shirt cranially and dorsally within a day.

remains (Haglund, 1989), as well as the presence of tracks or scat deposits in the immediate area.

Despite considerable evidence of carnivores (coyote, fox and domestic dog) at both research facilities, only three minor instances of scavenging were observed at site 1. All three involved modifications to articles of clothing, yet were easily discernible from those produced by insect activity. One instance involved the disarticulation and complete removal of both hindlimbs with socks from one specimen in the active decay stage. One limb was carried one meter then discarded, while the other was taken four meters from the body and the foot was removed from the sock and partially consumed. The distance the remains were transported and the tooth marks evident on the partially consumed remains indicated the action of carnivores. A second instance involved the displacement and partial consumption of a scarf wrapped around the neck of a large carcass in a state of advanced decomposition. Puncture marks produced by canine teeth were clearly visible along the frayed border of the scarf and minor soft tissue damage with similar tooth marks was also observed at the same time. A final example of canid activity resulted in the moderate chewing and fraying of a shirt tail. Again, clear puncture marks were evident in the fabric.

A further important characteristic of canid activity, evident in the second and third examples cited, was the clothing pattern produced by the tugging of the canid on the clothing. The unidirectional force and the weight of the body on the underlying clothes resulted in the restricted movement of the clothing under the carcass and

greater clothing displacement on the exposed areas of the body. This was in sharp contrast to the uniform movement of clothing above and below the carcass caused by maggot masses.

5.4.2 Discerning insect versus human induced clothing artifacts

In some instances, the source of clothing modifications which result from human interactions are easily discernible; assailants frequently remove the victim's clothing by cutting it off (Moreau and Bigbee, 1995b) or may even leave it folded neatly (Ressler, 1988). Clothing changes may also be the result of the action of the victim themselves in cases of suicide (Eckert, 1985) or accidental autoerotic asphyxiation (Spitz and Fisher, 1980), scenes which often resemble homicides.

Interpretation becomes more difficult in cases of clothing disarray, particularly in cases with an extended postmortem interval following the departure of the maggots from the carcass (Haskell *et al.*, 1997). The presence of pupal casings, deposited in the immediate vicinity or on the victim and their clothing, indicates prolonged postmortem insect colonization of the corpse (Catts and Haskell, 1990) and raises the possibility of insect generated clothing artifacts. Total exclusion of insects throughout the decomposition process is unlikely (Catts and Haskell, 1990); however, variables such as cold temperatures or postmortem disturbance of the body by humans or animals retard or arrest insect activity (Haskell *et al.*, 1997; Catts and Haskell, 1990) to a level insufficient to produce clothing changes. Thorough examination of the victim, clothing and vicinity for indications of the presence, duration and magnitude of

insect activity may be the only method of differentiating the causative agent of clothing changes.

5.5 CONCLUSIONS

Clothing disturbance patterns produced by postmortem insect activity mirror those derived from a perimortem sexual assault. Similarities between human induced changes and artifacts created by insects and carnivores increase with extended postmortem interval and complicate crime scene interpretation. Differentiating changes caused by the various agents requires careful examination of the entire scene, including the victim's remains, clothing and depositional environment. Failure to recognize the potential for this phenomenon may result in inaccurate conclusions and the misinterpretation of perimortem events (Haskell *et al.*, 1997).

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6. IDENTIFYING BIRD SCAVENGING IN FLESHED AND DRY REMAINS¹

6.1 INTRODUCTION

Postmortem scavenging of human remains by animals can complicate crime scene investigations through the dispersal of remains and the alteration or destruction of both scene and body (Haglund, 1992). The disarticulation sequences, scattering abilities and toothmark artifacts of canids and other carnivores are well-documented (Mann *et al.*, 1990; Haglund *et al.*, 1989; Blumenschine, 1986; Rossi *et al.*, 1994; Wiley and Snyder, 1989; Haglund *et al.*, 1988; Milner and Smith, 1989; Hill, 1979; Haglund, 1997). Rodents have also received some attention as vectors of transport and modifiers of bone (Haglund, 1992; Mann *et al.*, 1990; Haglund *et al.*, 1988).

However, the interaction between birds and human remains has been noted only briefly and without much detail (Bass, 1997; Rodriguez, 1997; France *et al.*, 1997).

Preliminary results from an ongoing field experiment in central Alberta using animal carrion as models for human decomposition indicate that several species of common birds such as crows and magpies produce significant postmortem artifacts in both flesh and bone and are important agents of transport of bone, jewelry and other materials associated with the remains. Observation and documentation of the scavenging behavior of birds (magpies, crows), rodents (field mice, moles) and canids (coyotes, domestic dogs) at the field site provides insight into the specific contributions of these species to the dispersal and modification of decaying remains in this region.

¹ A version of this chapter has been published. Komar, D and Beattie, O 1998. *Canadian Society for Forensic Science Journal* 31(3): 177-188.

6.2 MATERIALS

A total of 25 domestic pigs (*Sus scrofa*), all 80 kg in weight, were allowed to decompose at a field and woodlot biological research station at the southern border of the Edmonton, Alberta city limits from August to October, 1997. The majority of the pigs were fully dressed in adult-sized clothing, including underwear, socks or hose, shoes and jewelry, (earrings, necklaces and bracelets). The remaining pigs were deposited undressed, wrapped in plastic tarps or covered with synthetic fiber blankets. Depositional environments included full sun and partial and full shade surface sites as well as two hangings (full suspension by the neck, carcass completely off the ground). A summary of carcass placement is given in Table 6.1. All depositional sites were separated by a minimum of 50 m. The pigs were donated by a local processing plant; as part of the process, all were incised on the shoulder and hock with a 12 cm "X" which penetrated the skin and approximately 3 cm of the underlying fat. Detailed observations were made daily from August through November and photographic and weather records were maintained.

6.2.1 Scavenging species observed on site

Birds - The majority of the scavenging attributable to birds represents the action of two species from the order *Passeriformes* (perching birds) and the family *Corvidae* (Bovey, 1990). The most common and voracious scavenger was *Pica pica*, commonly known as the blackbilled magpie. The magpie has a ubiquitous presence throughout western North America (ranging from Alaska to eastern California), and is considered

TABLE 6.1 Summary of carcass placement, depositional environments and scavenging activity.

#	DATE PLACED	DEPOSITIONAL ENVIRONMENT	CLOTHING	INITIAL SCAVENGER	SECONDARY SCAVENGERS
1	05/08/97	surface, full shade	fully clothed	insects	birds
2	05/08/97	surface, full shade	fully clothed	insects	birds
3	05/08/97	surface, full sun	fully clothed	insects	birds
4	05/08/97	surface, full shade	fully clothed	insects	birds
5	05/08/97	surface, full sun	fully clothed	insects	birds
6	05/08/97	surface, full sun	fully clothed	insects	birds
7	13/08/97	surface, full shade	shower curtain	insects	birds
8	13/08/97	surface, full shade	none	insects	canids, birds
9	13/08/97	surface, full shade	blanket	insects	birds
10	27/08/97	hanging, shade	t-shirt, underwear	insects	birds
11	16/09/97	surface, partial shade	blanket	insects	birds
12	16/09/97	surface, full shade	shower curtain	birds	—
13	16/09/97	hanging, shade	t-shirt, underwear	insects	birds
14	16/09/97	surface, partial shade	none	birds	insects, rodent
15	16/09/97	surface, full sun	fully clothed	birds	—
16	16/09/97	surface, full sun	fully clothed	birds	rodent
17	16/09/97	surface, full sun	fully clothed	birds	—
18	28/09/97	surface, partial shade	blanket	birds	—
19	28/09/97	surface, partial shade	shower curtain	birds	—
20	28/09/97	surface, partial shade	none	birds	rodent
21	09/10/97	surface, partial shade	blanket	birds	canids
22	09/10/97	surface, full shade	none	birds	—
23	09/10/97	surface, partial shade	shower curtain	birds	canids
24	23/10/97	surface, shade	plastic	birds	canids
25	23/10/97	surface, shade	plastic	birds	canids

a garbage-raiding nuisance with a liking for dead flesh (Bovey, 1990; Salt and Salt, 1976; Godfrey, 1986). The other important scavenger was *Corvus brachyochos*, known as both the common (Salt and Salt, 1976) and American (Bovey, 1990) crow. The crow is a well-known feeder on carrion around farmsteads throughout North America (Salt and Salt, 1976) and was observed daily at the site through November. Common ravens (*Corvus corax*) are indigenous to the area and frequently scavenge

for food, particularly in winter (Salt and Salt, 1976). Ravens were seen on several occasions at the research facility but were never observed feeding directly on the carcasses. At least one species of owl was observed repeatedly at the site and in close proximity to the carcasses; however, identification to species was not possible because of the rapid departure of the birds whenever humans approached. Owls (order *Strigiformes*) are birds of prey and are not reported to scavenge for food (Salt and Salt, 1976; Godfrey, 1986). In addition, bird tracks in the snow observed on and around the carcasses on the mornings following light snowfalls were those of magpies and crows only; there was no evidence of the talons characteristic of owls.

Canids - Coyotes (*Canis latrans*) were observed daily from September through November; their presence at the site during the summer months was evident from scat and tracks, but they were not seen until early September. Domestic dogs (*Canis familiaris*), primarily medium to large working breeds, were consistently present and observed scavenging the carcasses repeatedly.

Rodents - Deer mouse (*Peromyscus maniculatus*) and Gapper's Red-Backed mouse (*Clethrionomys gapperi*) were observed in direct association with the carcasses.

Various types of moles, chipmunks and squirrels were also observed in the area but were never seen scavenging.

6.3 OBSERVATIONS

A summary of scavenging behaviour is found in Table 6.1. Initial scavenger refers to the the primary feeder within the first two weeks following carcass placement, while

secondary colonizers were those observed after two or more weeks. In most cases, the initial scavenger was responsible for consuming the majority of the carcass, while secondary scavengers contributed to the disarticulation, further consumption or bone modification of the remains.

Despite carcass depositions in August, no animal scavenging was observed until early September and, for the first two weeks, was exclusively the action of birds. Canid scavenging began in mid September and grew in frequency and degree throughout the months of October and November. Incidences of rodent scavenging were rare, isolated and occurred in late September and early October only.

Conditioning on the part of all animals played an important role in how and when the carcasses were scavenged. Only one carcass was scavenged at a time, with the animals returning on mass repeatedly to the carcass until little remained. This is similar to findings by France *et al.* (1997) indicating that hawks, vultures and other birds will visit a carcass repeatedly throughout the scavenging process. In consistently returning to a single carcass, the animals frequently traveled by other, fresher carcasses, suggesting that the animals preferred to return to an established food source rather than investigate more readily available resources.

The animal scavenging of each carcass began with the arrival of the magpies. Working in pairs, the magpies began to consume the flesh exposed by the incised "X"s on the shoulder and hock of each animal. On two carcasses, the magpies tore through the plastic tarps to expose the incisions and, in one case, displaced a jacket and t-shirt to access the incisions. The magpies returned repeatedly over several days, enlarging

the incisions, creating large cavities in the flesh (Figure 6.1), and attacking exposed soft tissues such as the eyes. Over the course of a week, magpies alone consumed the rear section of an 80 kg pig, from the anus to the lower border of the rib cage (Figures 6.2 and 6.3). This is contrary to a previous report by Bass (1997), in which unidentified species of birds associated with cadavers were believed to be feeding on insect larvae rather than decaying flesh. Scavenging by magpies continued on fresh carcasses for up to 30 days (cold temperatures during September through November delayed or prevented the onset of bloating in the carcasses, as well as preventing any insect colonization).

Except in one case, canids did not begin to scavenge a carcass until after the initial departure of the magpies. However, with the exposure of fresh flesh and abdominal contents by the canids, the magpies would return to the carcass and, on several occasions, dogs and magpies were seen feeding side-by-side. Crows were most frequently observed during this period as well. The scavenging by canids of each carcass in turn continued until only fragmented bone remained.

Rodent scavenging at this site was limited in one case to gnawing on a mummified snout and in several cases to gnawing on dry bone. In all cases, the rodents did not approach the carcass until after the departure of the other scavengers.

Of the 25 carcasses, three experienced extensive carnivore and bird scavenging, resulting in the almost total consumption of the carcass and widespread dispersal of the remaining elements. Another five were scavenged heavily by birds only, with significant consumption of flesh during the fresh stage (Figure 6.2 and 6.3). The head

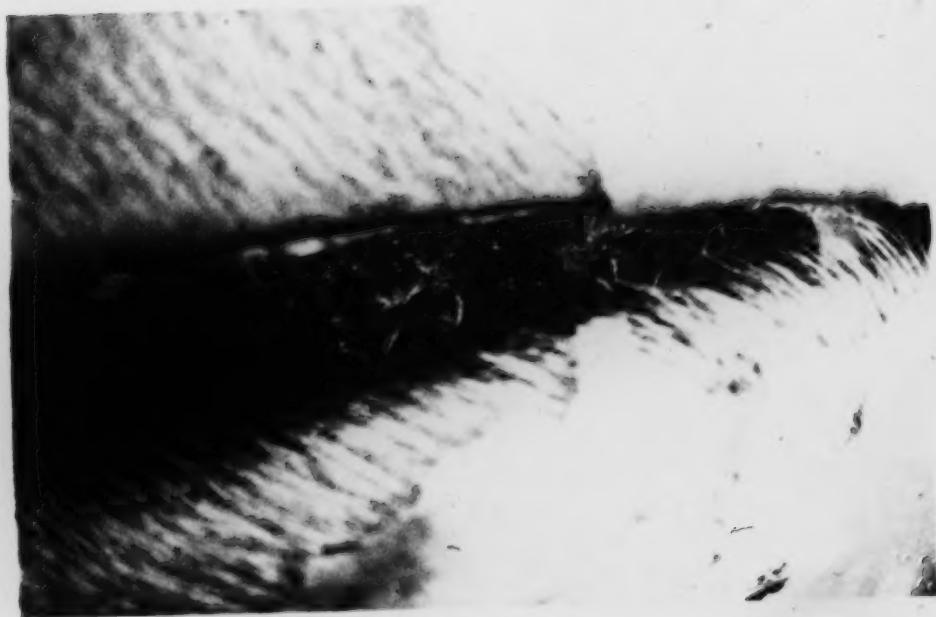


FIGURE 6.1

Close-up view of cavity created by bird feeding. Note the triangular-shaped punctures imprinted in the tissue.



FIGURE 6.2

Magpie scavenging to buttocks of an 80 kg pig, 26 days postmortem.



FIGURE 6.3

Continued magpie scavenging to buttocks of the same pig, 34 days postmortem. Core body temperature of pig during this period was $<0^{\circ}\text{C}$. Arrows indicate sharp "cut-like" border of torn skin.

of one carcass in the advanced stage of decay was dragged less than a meter from the body by canids. The remaining 16 carcasses (including the two hangings) experienced minor to moderate bird scavenging during the advanced stage of decomposition, when only desiccated skin, tissue and bone remained (Figure 6.4). By the end of October, every carcass had been scavenged to some degree by birds, while four had also been modified by canids and three by rodents.

Birds also proved to be important agents of transport. Previous reports detail the removal of head hair from corpses by birds for use in nest building (Bass, 1997; Rodriguez, 1997). However, in this study the birds demonstrated an ability to move more substantial objects, including bones (particularly ribs and fragmented cranial and facial bones), jewelry and clothing. On one occasion, two magpies were observed fighting over a black plastic bracelet that one had removed from a carcass. In a separate instance, a crow was seen flying away from a carcass carrying in its bill a plastic credit-card which had been placed in the rear pants pocket of the specimen's clothing. The card was later recovered on the ground 40 m from the carcass. Examination of the nearest magpie nest revealed a rib and an earring taken from a carcass located approximately 600 m away. A metatarsal was also recovered on the ground beneath the nest.

Crows and magpies are of similar size and possess a formidable wingspan. During take-offs and landings, the birds' wings produce sufficient air displacement to scatter

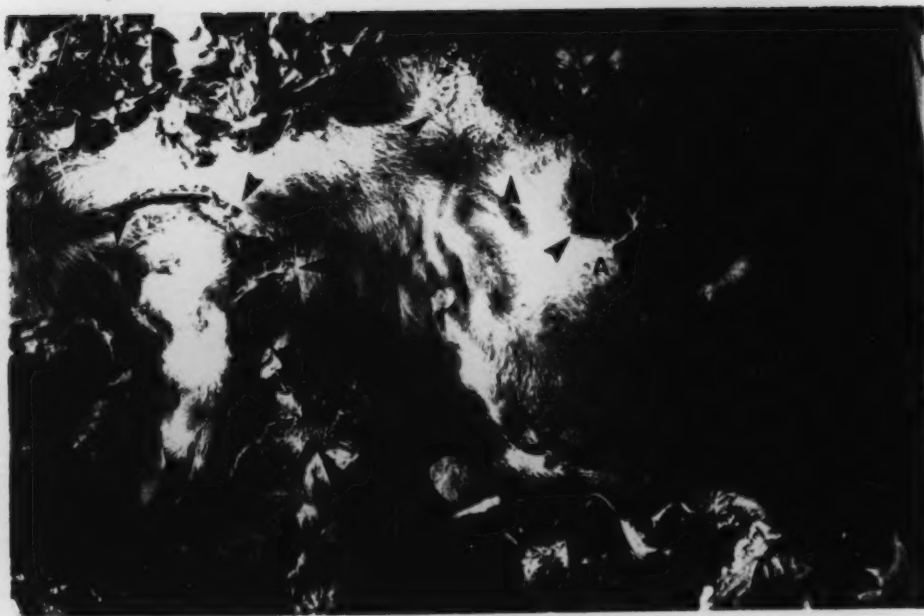


FIGURE 6.4

Cranium, neck and thorax of 80 kg pig in advanced stage of decomposition, shown 51 days postmortem. Arrows indicate areas of bird modification. Arrows labeled A and B illustrate sinewy appearance of adherent tissue strips.

bones from a skeletonized carcass up to a meter, disrupting the appearance of the scene. An example of this was seen in the case of one of the hanging pigs. Deposited in August, the internal organs and muscles were extensively colonized by insects while the skin mummified. Scavenging by birds to the incision at the hock allowed the dry bones to fall out of the skin and collect on the ground beneath the suspended carcass. The repeated arrival and departure of birds from the scene resulted in the scattering of the bones over an area of 16 square meters below the carcass.

6.3.1. Identifying Bird Scavenging in Fresh Remains

The pecking and tearing feeding style of scavenging birds such as magpies and crows produces characteristic triangular shaped punctures in flesh (Figure 6.1), as well as small strips of adhering tissue (see A and B in Figure 6.4) which are sinewy in appearance (Rodriguez, 1997). Varying bill morphologies produce differing types of wounds. The structure of chicken bills has been shown to create distinctive lesion patterns which are identifiable (Roll and Rous, 1991).

Scavenging birds also appear able to tear off skin in sheets, leaving straight edges in the remaining tissue which resemble cuts (see Figure 6.3); these surgical-like "cut" marks have been reported previously in hawk and vulture scavenging of pig carcasses (France *et al.*, 1997).

Bird wound patterning is also characteristic. In the presence of perimortem penetrating trauma, scavenging will normally begin and focus on the incisions, creating an expanding cavity into the flesh which will continue until bone is encountered. The cavities created by birds are easily discernible from the layered, differential destruction

of skin and underlying tissues characteristic of rodent scavenging illustrated by Haglund (1992).

The borders or margins of the penetrating trauma will be enlarged and, if the flesh remains soft, consumed, obliterating the evidence of the existing trauma. For this reason, caution should be exercised in analyzing and interpreting wounds in bodies which have been exposed outdoors for any length of time. In the absence of trauma, feeding focuses on exposed tissues such as eyes, tongue, nipples and anus (Figure 6. 2). Although able to perforate unbroken skin, birds primarily feed in areas where there is a defect or weakness, such as an abrasion. In several cases, a minor defect was enlarged into a round hole (of surprising symmetry) in the skin and a tube-like cavitation into the underlying flesh, creating a postmortem artifact which is similar in appearance to penetrating trauma.

6.3.2 Identifying Bird Modification in Desiccated Flesh

In this study, scavenging of the carcasses by birds continued throughout the advanced decomposition stage. Both crows and magpies had no difficulty perforating the often leathery mummified skin of the carcasses and created cavities in the desiccated flesh larger than those seen in fresh remains. In three carcasses, a cavity originating at the anus extended well into the thoracic cavity while the overlying skin of the abdomen was left intact. At this stage, the birds did appear to be feeding on the remaining dead insect larvae, which is in keeping with a report by Bass (1997).

Wound patterning in desiccated remains is less predictable. Small circular wounds are pecked into the skin anywhere it is exposed on the carcass (Figure 6.4). Larger cavities may extend into the thorax, abdominal or pelvic cavities.

6.3.3 Differentiating Bird Artifacts in Bone from those of Canids and Rodents

In an apparent effort to access the maggots situated in the cancellous portions of bone, birds will remove the outer cortical bone layer and create conical punctures in the cancellous bone (Figure 6.5). Birds produce no symmetry or pairing of punctures, similar to those created by the canine teeth of canids or the incisors of rodents. The conical impressions created by the beak are easily differentiated from the paired striations characteristic of rodent gnawing (Figure 6.6) [described in detail in Haglund, 1992] and the v-shaped toothmarks typical of carnivores (Figure 6.7) [described in detail in Haglund, 1997]. The conical impressions occur randomly and frequently overlap. Areas of damage are isolated and contained. Just as birds will focus on one area of flesh, gouging a single cavity, so too will they focus on one area of bone, removing the cortical layer and creating a depression within the cancellous bone (Figure 6.5).

The location and extent of bone damage also aid in discerning bird from carnivore and rodent modifications. Bird artifacts are usually in the center of a large bone surface area, such as the shaft of long bones or the flat portions of irregular bones such as scapulae and innominates. This is in contrast to carnivore scavenging which tends to focus on extremities and the ends of long bones (Haglund *et al.*, 1988; Haglund, 1997) or rodent gnawing, which is commonly seen on the epiphyseal cartilages and

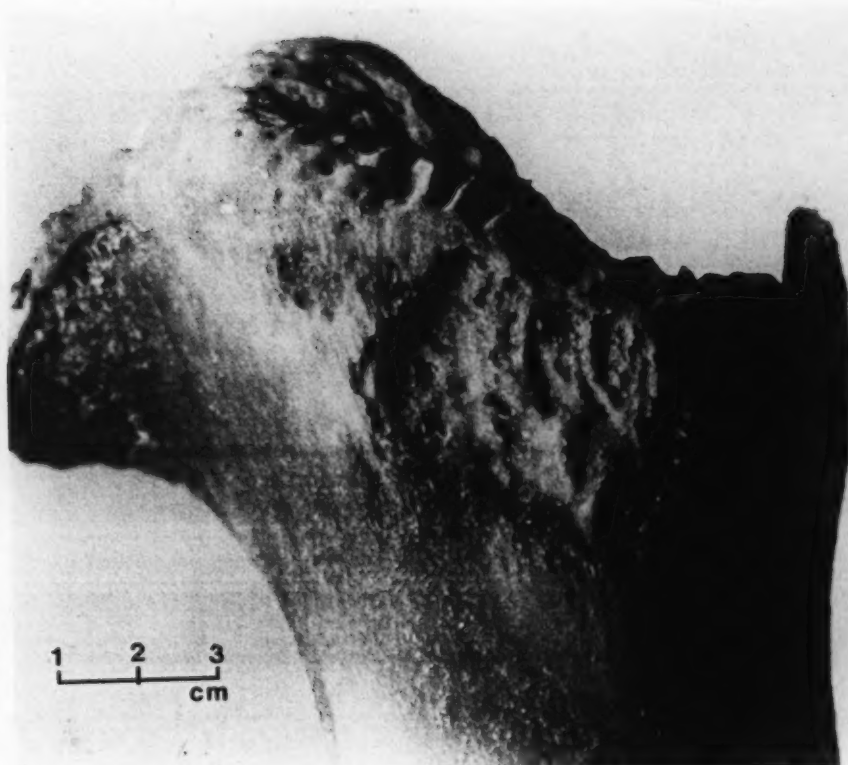


FIGURE 6.5

Example of bird modification to bone, as seen in close-up view of proximal femur (minus unfused epiphysis). Photo credit: Cyril Chan.



FIGURE 6.6

Example of rodent gnawing on bone, as seen in close-up view of superior articular facet on the sustentaculum tali of a calcaneus. Photo credit: Cyril Chan

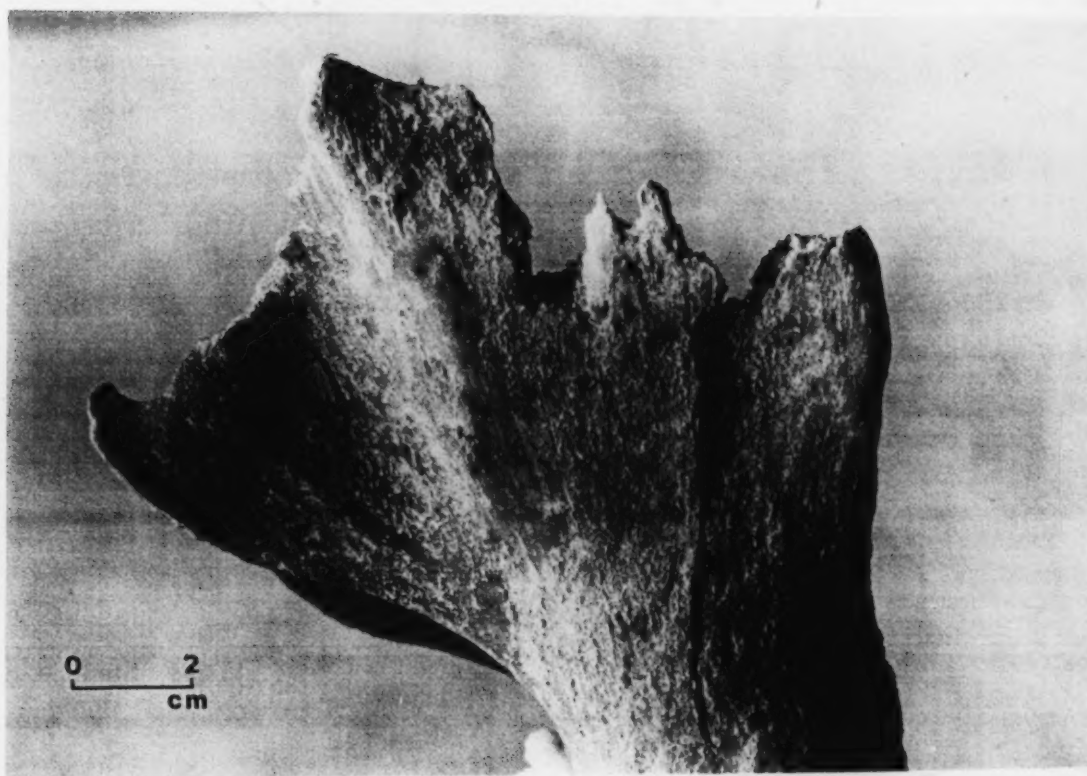


FIGURE 6.7

Example of carnivore chewing on bone, as seen in close-up view of the left ascending ramus of the mandible. Photo credit: Cyril Chan.

long bones of sub-adults (Haglund, 1992; Haglund *et al.*, 1988). Bird damage is also restricted to one surface or plane of a bone, compared with the impressions left by both the upper and lower dentition of rodents and canids on opposing sides of a bone or adjacent planes on differing angles created by crests or articular surfaces (Figure 6.6). Finally, carnivore scavenging normally results in far greater destruction and consumption of bone than does the actions of birds and rodents.

Case Study

In April 1994, hikers discovered human remains near a river bank 140 km west of Edmonton. The skull, along with the first four cervical vertebrae and the mummified skin of the thorax, abdomen and right arm, was hanging 10 feet (3 m) above the ground by a nylon rope tied to a tree. Twenty-two postcranial bones were recovered on the ground below, along with a set of handcuffs and the remnants of underwear. The remains were subsequently identified as those of a man who had been reported missing 10 years prior.

Examination of the remains were conducted by Owen Beattie at the time of recovery. A second examination of the osteological remains was undertaken by the author in 1997; the desiccated skin, cervical vertebrae and three post-cranial bones were no longer available at the second exam.

Three distinct types of postmortem scavenging artifacts can be discerned on the postcranial bones recovered. The paired striated grooves characteristic of rodent gnawing are evident on the scapular processes and condyles of long bones. Canid gnawing has destroyed the borders of the scapula and innominate as



FIGURE 6.8

Close up view of inferior aspect of left femoral neck and head from case study. Note canid gnawing to head. Arrows indicate area of bird artifact. Photo credit: Cyril Chan

well as long bone extremities. Canid v-shaped toothpunctures are numerous across the blade of the innominate and the femoral head (Figure 6.8). Bird modification is evident on the inferior aspect of the neck of the left femur (Figure 6.8). The cortical bone has been removed and the underlying cancellous bone is hollowed out by a series of random, well defined beak-shaped impressions. This artifact can be discerned from the developmental anomaly known as the cervical fossa of Allen (Angel, 1964; Finnegan, 1978) as follows: 1) the defect occurs on the inferior, posterior aspect of the femoral neck, in contrast with Allen's fossa which occurs on the anterior superior margin; 2) the defect displays no thickening or reactive response to its border, as is sometimes seen in Allen's fossa; and 3) the defect measures in excess of 3 cm in diameter, in contrast to the 1 cm² defects reported for Allen's fossa (Angel, 1964; Finnegan, 1978).

This case study illustrates that bird modifications to bone remain identifiable in cases with extended postmortem intervals and that such artifacts are easily discernible from those created by rodents and canids.

6.4 CONCLUSIONS

Contrary to the findings of Bass (1997) in the Tennessee area, birds do appear to be a major factor affecting decay rates in the central Alberta region as they are capable of consuming a considerable amount of flesh in a short period of time.

Recognizing bird modifications to scenes and remains is crucial in accurate crime scene interpretation. The potential for birds to obscure or destroy the cause of death or create postmortem artifacts which mimic perimortem trauma must be kept in mind when analyzing exposed remains, particularly in rural settings. Differentiating bird from canid and rodent scavenging is also important in proper scene analysis.

Finally, scene interpretation and positive identification can be confounded in cases where evidence is separated by unexpected distances (Haglund and Reay, 1993). Birds are capable of transporting key elements essential to the identification process such as jewelry and facial bones over considerable distances. It is recommended that any search plan to recover scavenged remains includes an examination of nearby nests.

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7. COMPARISON OF FIELD VS CASE STUDY OBSERVATIONS TO ASSESS THE VALIDITY OF ANIMAL ANALOGUES IN HUMAN DECOMPOSITION EXPERIMENTS

7.1 INTRODUCTION

The goal of taphonomic model building is to understand the operation and products of current and past taphonomic processes (Bonnichsen, 1989). Assumptions and analogic reasoning are inherent in any attempt to use observation of bone modification to identify or infer the taphonomic mechanism responsible (Gifford-Gonzalez, 1989; Bonnichsen, 1989). Actualistic studies have been used to bridge this gap between current observations and past processes.

Taphonomic issues such as decay rates and animal scavenging are relevant to forensic death investigations and seem a logical subject for actualistic experiments. Given the ethical and moral implications of using human cadavers in such experiments (Schoenly *et al.*, 1991), researchers frequently rely on animal models to study decay processes (Komar and Beattie, 1998a). Animal analogues have been used in actualistic studies in taphonomy (Machel, 1996), forensic taphonomy (France *et al.*, 1992, 1997; Komar and Beattie, 1998a, 1998b, 1998c; Micozzi, 1986), scavenging (Adair and Kolz, 1998; Willey and Snider, 1989) and most notably entomology (Schoenly *et al.*, 1991; Anderson and VanLerhoven, 1991; Payne *et al.*, 1968; Dillon, 1997; Shean *et al.*, 1993; Hewadikaram and Goff, 1991; VanLerhoven, 1997). While animals used as human analogues have included deer (Willey and Snider, 1989), rats (Micozzi, 1986) and dogs (Reed, 1958), the most common model remains domestic pigs (Anderson and VanLerhoven, 1996; Dillon, 1997; VanLerhoven,

1997; Komar and Beattie 1998a, 1998b, 1998c; Payne *et al.*, 1968; Shean *et al.*, 1993; Schoenly *et al.*, 1991; France *et al.*, 1992, 1997; Hewadikaram and Goff, 1991).

The validity of any actualistic study is based on the credibility of the analogies it employs (Binford, 1981; Haglund, 1991; Gifford-Gonzalez, 1989). It has been argued that domestic pigs (*Sus scrofa*) are the best models for humans because of their relatively hairless skin, their fat-to-muscle ratio (France *et al.*, 1992) and their omnivorous diet with equivalent digestive tract fauna (Anderson and VanLaerhoven, 1996). However, it is important to note that there have been no published field studies offering direct comparisons of pig carcasses and human cadavers to test this assertion (Schoenly *et al.*, 1991).

While such a field study would prove optimal, the validity of porcine models in human decay experiments may also be assessed through comparisons of detailed forensic case studies and animal model field studies conducted in similar environmental conditions.

The purpose of this chapter is to compare the findings of the records survey and case studies of hangings in Alberta (Chapter 3) to observations from a field study of suspended pig carcasses to determine the appropriateness of the animal analogue and assess its predictive and illustrative value.

7.2 METHODS AND MATERIALS

7.2.1 Record survey and case studies

A computer search of files from the Office of the Chief Medical Examiner (Alberta Justice) from January 1, 1990 through December 31, 1997 selected cases in which the cause of death was attributed to hanging. Files included the autopsy report and Medical Examiner's summary as well as associated police reports and photographs where available. Information was recorded on the age, sex and ethnic affinity of the individual, the manner of death, the location of the body and its decompositional state at recovery, the month in which the hanging took place, the type of ligature used and the elapsed time between death (when the individual was last seen alive) and body recovery.

Findings from the records survey were used to establish parameters for a subsequent field study. Ligature type, month and location of hanging, clothing and other variables shown to be common in outdoor hangings were replicated in the field experiment.

Results of the record survey have been submitted for publication (Komar *et al.*, 1999). Included in this manuscript are three case studies involving postmortem intervals of 5 weeks, 16 months and 10 years respectively.

7.2.2 Field Study

Four pigs, all 80 kg in weight, were suspended by the neck using a hangman's noose and allowed to decompose at a research station at the southern border of the Edmonton city limits from August, 1997 through December, 1998. All pigs were

dressed identically, each with a t-shirt, underwear and socks. Depositional environments consisted of partial shade, with each hanging suspended from a gallows between two trees. Two pigs were completely suspended, while two were partially suspended with their hindlimbs in contact with the ground. Two pigs were placed during summer (August, 1997 and July, 1998), one in fall (September, 1997) and one in the spring (May, 1998). The research station is primarily farmed fields, although all the hangings were located in a large wood cut between fields. The hanging sites were separated by a minimum of 20 m. The facility is unfenced and the carcasses were fully accessible to all scavengers. The research station is home to a large number of coyotes and scavenging birds such as magpies and crows (Komar and Beattie, 1998b), as well as numerous domestic dogs. The pigs were donated by a local processing plant; as part of the slaughtering process, all had been incised on the shoulder and hock with a 12 cm X which penetrated the skin and underlying fat.

The hanging specimens comprised a portion of a larger field study. At the same time each of the four hanging carcasses were suspended, an additional six pigs were surface deposited at the same facility. All were identical to the hanging carcasses in that they were 80 kg, incised on the hock and shoulder and were fully dressed. Of each set of six, three were deposited in full sun and three in partial shade. All were equally accessible to scavengers. A cloth ligature was applied to the neck of 5 of the 24 terrestrial pigs. Reports on the terrestrial carcasses have been published previously (Komar and Beattie, 1998a, 1998b, 1998c); observations relevant to the hanging carcasses will be discussed for comparative purposes only.

2

7.3 RESULTS / OBSERVATIONS

A full report of the records survey is given in Chapter 3. Outdoor hangings were found to be common (55 cases out of a total 478 or 11.5%) and occurred in every month of the year except January. Suspension from a tree, usually in a rural wooded area, with a rope ligature was the most common outdoor scenario.

Observations from the suspended carcass field study were surprisingly consistent, despite the date of initial carcass suspension. All blowfly oviposition occurred first at the noose, with flies depositing a thick layer of eggs completely covering the ligature (Figure 7.1). Smaller deposits were seen later in the ears, anus and hock incisions. Maggot masses developed in the thorax and abdomen of each carcass and pools of fluid and maggots collected below the suspended animal. After approximately 6 weeks, the muscles of the anus and buttocks would collapse, releasing a mass of decomposed viscera, maggots and bones onto the ground below (Figure 7.2). Maggot feeding would continue until both cavities were empty, leaving only a hollow, mummified shell of skin (Figure 7.3). No maggot masses were observed or evident in the mouth, nose or eyes of any carcass.

Postmortem animal scavenging was initially restricted in all carcasses to isolated instances of bird pecking at the hock incisions and facial features, as well as feeding on the maggots. Canid scavenging was observed only during the advanced and dry decompositional stages and focused on the buttocks and lower extremities accessible in the partially suspended carcasses (Figure 7.4). Canid and bird scavenging



FIGURE 7.1

Close up view of the neck of specimen 2, 4 days postmortem. Note the thick layer of blowfly eggs deposited along the noose, with a smaller deposit in the ear.

**FIGURE 7.2**

View of lower extremities and ground below specimen 1, seen 54 days postmortem. Note the defect to the buttocks and the mass of viscera, bones and maggots on the ground and the displacement of the underwear.



FIGURE 7.3

Specimen 1, photographed 91 days postmortem. Skin is completely mummified and hollow. Note scatter of bones beneath carcass.



FIGURE 7.4

Close-up view of the abdomen and lower extremities of specimen 2, photographed 255 days postmortem. Note the absence of the socks and underwear.

of the oldest carcass (Specimen 1, Table 7.1) continued throughout each fall and winter until the entire lower half of the carcass was absent (Figure 7.5). Scavenging and dispersal of the dry bones beneath the carcasses began immediately following their deposition and continued throughout the experiment. A summary of postmortem scavenging activity is given in Table 7.1.

TABLE 7.1 *Summary of suspended 80 kg, clothed pig carcasses.*

#	DATE HUNG	DEGREE OF SUSPENSION	POSTMORTEM INSECT ACTIVITY	POSTMORTEM ANIMAL SCAVENGING
1	08/27/97	partial, legs on ground	eggs at noose/ maggot masses in thorax, abdomen	initially birds then canid gnawing to lower extremities
2	09/16/97	partial, legs on ground	eggs at noose, anus/ mag. mass in abdomen, thorax	initially birds then canid gnawing to lower extremities
3	05/06/98	full	eggs at noose, anus/ mag. mass in abdomen, thorax	scattering of bones under carcass by canids/birds
4	07/15/98	full	eggs at noose, anus, eyes / mass in thorax, abdomen	scattering of bones under carcass by canids/birds

Mummification of the skin and muscles of the remaining limbs was extensive. The head and face of each carcass were completely mummified, retaining all hair (including structures analogous with eyebrows and eyelashes) and all four carcasses retained full dentition *in situ* (Figure 7.6).

Changes to the clothing of each carcass were also consistent. The underwear of all four carcasses was displaced during the avulsing of the viscera and bones (Figure 7.2)



FIGURE 7.5

Specimen 1, photographed 458 days postmortem. Canid scavenging has removed the hind section of the carcass.



FIGURE 7.6

Specimen 1, photographed 186 days postmortem. Note the retention of full dentition, hair and "eyelashes" as well as the minor bird scavenging to eye sockets.

and were eventually carried off by animal scavengers. The socks were removed and dispersed during the course of canid scavenging of the lower extremities (Figure 7.4). All t-shirts remained on the torsos and were discoloured by large streaks of decomposition fluid emanating from the head and neck of each carcass.

7.4 DISCUSSION

Comparisons of the results of the hanging field study to the three cases studies detailed in the records survey (Komar *et al.*, 1999) reveal five major consistencies. Comparisons of these consistencies with observations of the terrestrial carcasses are included to identify those features characteristic of or associated with hanging. Field study observations provide insight into the taphonomic process responsible for each modification.

7.4.1 No postmortem tooth loss

The individuals described in the three cases studies retained full dentition, *in situ*, (Figure 7.7) despite PMIs of 5 weeks, 16 months and 10 years (Komar *et al.*, 1999, Chapter 3). All suspended carcasses also experienced no postmortem tooth loss (Figure 7.6). All 24 terrestrial carcasses lost a minimum of 2 or more anterior teeth postmortem.

Postmortem tooth loss has previously been reported to be the result of the deterioration of the soft tissues (primarily the periodontal ligament) which anchor the



FIGURE 7.7

Close up view of the face and cranium of the individual described in case study 3, photographed after a PMI of 10 years. Note the retention of full dentition and eyelids, as well as facial and scalp hair

tooth to the alveolar bone (McKeown and Bennett, 1995; Haglund, 1997).

Postmortem insect scavenging has been identified as one of several interrelated factors affecting soft tissue decomposition (Mann *et al.*, 1990), thereby influencing rates of postmortem tooth loss (McKeown and Bennett, 1995).

Differences in maggot mass development and feeding behaviour observed between the terrestrial and suspended carcasses may explain the patterns seen in the field study. Oviposition began at the noose of the suspended carcasses and masses developed in the thoracic cavity. No masses were observed in the cranial orifices. Oviposition occurred initially in the natural orifices of the head of all terrestrial pigs. Without exception, maggot masses were first observed in the mouth of all terrestrial carcasses. Maggots were frequently seen on and below the gum line (Figure 7.8). The movement of the mass often displaced the anterior teeth (Figure 7.9) and in 10 specimens resulted in the transportation of incisors up to 13 cm from the jaws.

Maggot masses have a demonstrated capacity to move sizable objects, including bones, dentures (Haskell *et al.*, 1997) and clothing (Komar and Beattie, 1998c). McKeown and Bennett (1995) report tooth loss to be most rapid in individuals deposited in summer and in direct sunlight, factors associated with increased carrion insect activity (Rodriguez and Bass, 1983; Dillon, 1997; Komar and Beattie, 1998a).

7.4.2 Extensive mummification and retention of facial soft tissue features

Two of the three individuals described in the case studies experienced extensive mummification of the face, skin and extremities (Komar *et al.*, 1999). Facial skin was desiccated, forming a parchment like mask, while finer features such as eyelids and



FIGURE 7.8

Close up view of the snout of one of the terrestrial carcasses, photographed 7 days postmortem. Note the maggots below the gum and the mass centered in the oral cavity.



FIGURE 7.9

Close up view of the snout of the same terrestrial carcass shown in Figure 7.8, photographed 10 days postmortem. Note the two incisors displaced by the maggot mass at the tip of the snout.



FIGURE 7.10

Close up view of the eyes and nose of the individual described in Case Study 2. Note the desiccated skin and retention of the eye lids and lashes.

lashes (Figure 7.10) and facial hair (Figure 7.7) remained. Case study 3, with a PMI in excess of 10 years, featured complete mummification of the skin of the thorax and abdomen and right arm in a rigid hollow mass measuring 122 cm in length (Komar *et al.*, 1999).

Similar mummification patterns were seen in the four suspended animal analogues. Desiccation of the cranial skin preserved the majority of facial features (Figure 7.6). After several months, the postcranial skin of the thorax and abdomen had dried to a hard, elongated shell (Figure 7.3) and the fore and hind limbs had completely mummified.

Degree of skin desiccation in the terrestrial pigs varied widely. Only exposed skin (not covered by clothing or in contact with soil) mummified. Desiccation rates were faster in the sun exposed pigs, although the amount or percentage of mummified skin was greater in the shaded carcasses.

Soft tissue mummification occurs in dry environments (Evans, 1963; Galloway *et al.*, 1989). Temperature extremes, both hot and cold, can accelerate mummification (Clark *et al.*, 1997). Desiccation may even occur in snow covered remains (Ambach *et al.*, 1992).

The extent of the postcranial desiccation of suspended remains appears related to the increased airflow and circulation associated with hanging. Additional factors may include the lack of water absorption from soil and the concentration of maggot masses within the carcass. Maggot masses were often observed overflowing onto the ground surrounding terrestrial carcasses, allowing greater opportunity to feed on skin and

extremities. Masses observed on the suspended carcasses remained contained within the thorax and abdominal cavities or were pooled on the ground below the carcass.

The mummification and preservation of facial features seen in two of the three case studies and in all suspended animal models may result from both increased air circulation and the feeding behaviour of maggot masses. Descriptions of three surface deposited human cadavers in Tennessee illustrate that insect oviposition and colonization normally begins at the eyes, nose and mouth and that subsequent feeding destroys most soft tissue facial features (Watkins, 1983). This is consistent with another report by Haskell *et al.* (1997). As previously noted, maggot masses were not observed in the cranial orifices of the hanging carcasses. The retention of fine structures such as eyelashes seen in case studies 2 and 3 (Figures 7.7 and 7.10) is unlikely in the presence of maggot masses and suggests that insect colonization of these bodies was concentrated postcranially.

The exception to this finding is described in case study 1, in which the facial features of the individual were destroyed by insects (Komar *et al.*, 1999). Several factors may explain this variation. The first is that descriptions of this case study were drawn from brief autopsy notations; no photographs of the scene or remains were available. Specific details as to the state of the remains were not unavailable. Secondly, the postmortem interval in this case was 5 weeks, covering the months of July and early August, the period in which temperatures and insect activity in this region are greatest. Terrestrial pigs deposited in July and August experienced accelerated and voracious maggot feeding compared to those deposited in spring and

fall. Maggots were capable of completely skeletonizing an 80 kg carcass in under two weeks. Such rapid consumption of soft tissues reduces the likelihood of mummification. Finally, the body was in a seated position under a tree, allowing maggot masses greater freedom of movement and the potential for more surface feeding.

7.4.3 Blowfly egg deposits along the ligature

There is evidence of oviposition at the neck and noose of all three case studies. Insect activity, described in the autopsy report as "defects from maggots", was noted in the neck area surrounding the ligature in case study 1. In the second case study, blowfly egg deposits were visible on the loops of the ligature (Figure 3.2). Pupal casings were recovered from the towel used to pad the ligature in case study 3.

A thick layer of blowfly eggs was deposited along the ligature of all suspended carcasses, regardless of their season of deposition (Figure 7.1). These "egg collars" were observed within days of carcass deposition and would slowly disintegrate in subsequent weeks.

For comparative purposes, a cloth ligature was applied tightly to the necks of 5 of the 24 terrestrial carcasses at the time of their deposition. No egg deposits were evident along any of these five ligatures (Figure 7.11).

The weight of the suspended carcass against the noose abraded or tore the underlying skin, with fluid emanating from the abrasion. Blowflies are attracted to open trauma, such as knife or gunshot wounds (Haskell *et al.*, 1997). The non-

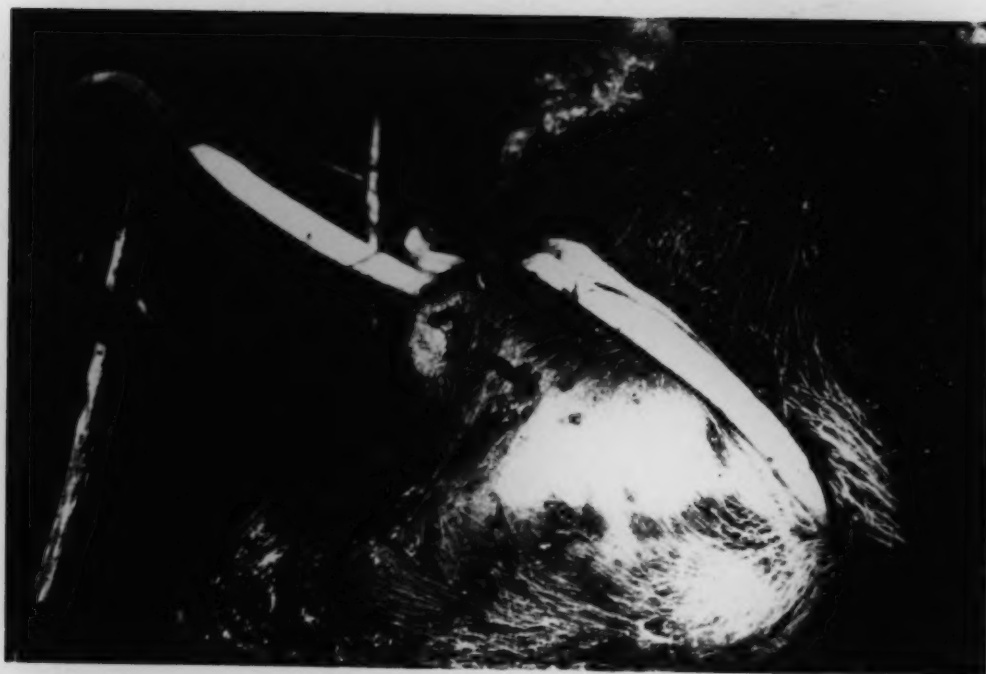


FIGURE 7.11

One of the five terrestrial carcasses, deposited with a ligature, photographed 17 days postmortem. Note the maggot mass under the clothes at the neck line, egg deposits in the fabric of collar, yet the absence of egg deposits along the ligature.

weightbearing nature of the terrestrial ligatures may explain the differences in observed blowfly oviposition.

7.4.4 Accumulation of bones below the remains, with subsequent dispersal by animal scavenging

Two case studies involved only partial suspension of the body and insufficient PMIs to result in skeletonization and disarticulation of remains. The third case study, with a PMI of 10 years and full suspension of the body, best illustrates the interaction between the remains and animal scavengers. In case 3, 22 postcranial bones were found scattered on the ground below the suspended remains. Most of the bones showed postmortem modifications by canids, rodents and birds (Komar and Beattie, 1998b).

All suspended carcasses displayed a similar pattern. As the carcasses decomposed, hollowed and mummified, dry bones fell to the ground (Figure 7.3). The bones were subsequently scattered throughout the surrounding woods by scavenging animals, including canids, rodents and birds (Komar and Beattie, 1998b).

7.4.5 Canid scavenging restricted to lower or dependent extremities

Case study 2 featured an individual suspended in a sitting position, with his legs extended. Canid scavenging was confined to the legs (despite the presence of jeans and boots) and exposed hands (Figure 3.3).

Two of the four animal analogues were partially suspended, with their hindlimbs in contact with the ground. The lower portions of these carcasses were scavenged repeatedly (Figure 7.4) and eventually completely consumed (Figure 7.5).

Access appears to be the determining factor, with variables such as the size of the scavenger and the suspended height of the carcass influencing the patterns of consumption. It is interesting to note that bird scavenging was observed to all regions of the suspended carcasses and that rodent gnawing is evident on the noose in case study 2 (Figure 3.2) as well as to the forelimb of one of the partially suspended carcasses.

7.4.6 Credibility and predictive value of animal analogues

Small sample sizes for both the case studies and field experiments prohibit conclusive results and all findings must be considered preliminary. Similarities, however, in observations between human case studies and animal analogues suggest that the taphonomic process responsible for each modification acts on both humans and pigs. More importantly, the artifacts and modifications created by each taphonomic mechanism physically manifest in similar ways, indicating the predictive value of the analogues.

7.5 CONCLUSIONS

Comparisons of case and field study observations suggest that large size domestic pigs are an appropriate model for humans in taphonomic decomposition experiments. Both human and animal subjects presented a wide variety of postmortem artifacts and modifications, including retention of full dentition and facial features, extensive mummification of skin and soft tissues, blowfly oviposition at the ligature, collection of bones below the suspended remains and canid scavenging restricted to dependent

body regions. The taphonomic mechanism responsible for these modifications appears similar in humans and the animal analogues, indicating the predictive value of the animal model.

Comparisons with terrestrial carcasses indicate that this combination of modifications may be considered characteristic of hangings and that one feature, the presence of blowfly egg deposits at the ligature, may be a unique consequence of body suspension.

Further research to increase sample size is suggested.

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8. THE USE OF CADAVER DOGS IN LOCATING SCATTERED, SCAVENGED HUMAN REMAINS: PRELIMINARY FIELD TEST RESULTS¹

8.1 INTRODUCTION

Specially trained air scent detection canines (*Canis familiaris*) are commonly used by law enforcement officers to detect narcotics, explosives or contraband and by fire investigators to detect the presence of accelerants. Dogs are also used by police, military and civilian groups to locate lost or missing persons, as well as victims of natural or mass disasters. A further subspecialty is "cadaver" searching or the use of dogs to locate buried or concealed human remains.

Research on the efficacy of scent detection dogs has been limited and the bulk of the literature consists of anecdotal reports in non-refereed journals (Kurz *et al.*, 1996). Scientific studies have focused primarily on accelerant detection (Kurz *et al.*, 1996; Tindall and Lothridge, 1995; Kurz *et al.*, 1994) and the validity of scent detection line-ups (Schoon, 1997, 1998). Previous reports on the use of cadaver dogs have focused exclusively on their use in detecting burials (Owsley, 1995; France *et al.*, 1997) and contain only anecdotal case reports (Owsley, 1995) or preliminary results (France *et al.*, 1997).

Recent forensic investigations in the Edmonton, Alberta region using air scent detection dogs to recover animal scavenged human remains indicate that the role of the cadaver dog could be expanded to include locating scattered body elements. Postmortem animal activity resulting in widely dispersed remains is a common

¹ A version of this chapter has been published. Komar, D 1999. *Journal of Forensic Sciences*, 44(2): 405-408.

component of cases involving outdoor, decomposed remains in the region (Komar, 1998). Recovery in these cases is often confounded by thick coverings of snow or leaf litter which further conceal the remains. Three recent cases involving extended postmortem intervals (PMI) and widely scattered human remains demonstrated that air scent detection dogs effectively located dispersed remains but that additional training would be required. A research and training program was then developed to examine the use of cadaver dogs in search strategies involving dispersed remains.

8.2 MATERIALS AND METHODS

Eight dog and handler teams volunteered to participate in the training and research program. The breed and experience level of each dog is given in Table 8.1. One team consisted of a Royal Canadian Mounted Police (RCMP) officer and his service dog; the remaining teams were members of the RCMP Civilian Search and Rescue Service Dog Program (Wiseman, 1995). Weekly training sessions began in late November, 1997 and continued until the end of January, 1998. During training sessions, each team was given a separate search area and the handlers were advised of the number and type of articles hidden in their areas. If all articles were not found during the initial search, handlers were advised of the location of the missing articles and directed the dogs to those items. Search area size varied during the training sessions, ranging from 10 x 10 meter squares to 60 x 60 meter squares. Scent sources (referred to by the dog handlers as "hides") were placed between 1 hour and 1 day prior to the search.

The field trials consisted of blind searches in which the handlers were not informed as to the number or type of hides. Search areas were consistently 20 m x 20 m.

Separate search areas were provided for each team and different locations were used for each field test; no search areas were used more than once to avoid contamination. Scent sources were randomly placed within each area by the author a minimum of 24 hours prior to the search. No scent sources were buried during the testing; however, all hides were not visible to the handlers or dogs. All items were concealed by leaf

TABLE 8.1 *Performance of individual dog teams, including number of training sessions and field trials attended.*

#	BREED	EXPERIENCE	# TRAINING	# TRIALS	% RECOVERY
1	Standard Poodle	civilian, certified	3	8	55
2	German Shepherd	civilian, certified	2	9	60
3	Yellow Labrador	civilian, certified	5	2	71
4	Doberman	civilian, certified	5	7	79
5	Mallinois	civilian, not certified	4	8	86
6	German Shepherd	civilian, certified	3	8	90
7	Border Collie	civilian, not certified	7	10	93
8	German Shepherd	RCMP, PSD #508	7	9	95

TABLE 8.2 Summary of environments, field conditions, scent sources and recovery rates of training sessions and field tests.

TEST #	ENVIRONMENT	WEATHER CONDITIONS	SCENT SOURCE	# OF TEAMS	% ITEMS FOUND	COMMENTS
TRAINING SESSIONS						
T-1	open grass field - search areas 15 m ²	-5 C, light wind and snow cover	jewelry and clothing	4	100	items visible. Average search time (AST): 4 min.
T-2	grass field w/ trees - search areas 15 m ²	-8 C, light wind	human bone	7	77	4 teams found all items in their areas. AST: 11 min.
T-3	grass field with trees - areas 10 m ²	-7 C, light snow cover, no wind	human bone	6	100	handlers knew # of items and worked until all were found. AST: 11 min.
T-4	plowed field w/ 1 ft wheat - areas 60m ²	0 C, light wind	scent tubes	5	60	scent tubes not suitable. AST: 22 min.
T-5	plowed field w/ 1 ft wheat - areas 20 m ²	-2 C, light wind	human bone / fluid containers	6	100	areas searched till all items found. AST: 10 min.
T-6	open field w/trees & grass - areas 20 m ²	2 C, light gusty wind	clothing/ fluid containers	4	100	areas searched till all items were found. AST: 8 min.
T-7	plowed field with wheat stubble - search areas 10 m ²	-30 C, 25 cm of snow no wind	fluid bags	4	100	one dog could not search because of cold temperatures. AST: 6 min.

FIELD TRIALS

(All search areas 20 m x 20 m)

F-1	open grass field	-3 C, 15 cm of snow light wind	fluid bags/ animal bone /clothing	6	100	articles placed 48 hrs prior AST: 18 min.
F-2	plowed field with wheat stubble	-3 C, 15 cm of snow light wind	fluid bags/animal bone/clothing	6	88	articles placed 48 hrs prior AST: 18 min.
F-3	woods	7 C, 15 cm of snow no wind, sunny	human, animal bone	8	63	articles placed 24 hrs prior, 1st time in woods. AST: 20 m.
F-4	woods, dense brush	2 C, 19 cm of crusted snow, light wind	human bone	7	90	articles placed 24 hrs prior AST: 14 min.
F-5	woods	-8 C, 20 cm crusted snow, moderate wind	human, animal bone/fluid bags	7	95	articles placed 30 hrs prior. AST: 12 min.
F-6	woods, dense brush	-11 C, 18 cm crusted snow, gusting wind	animal bone/fluid bags	5	70	articles placed 48 hrs prior. AST: 13 min.
F-7	woods	10 C, 8 cm melting snow, very light wind	decomp. fluid soaked in ground	5	57	deposited 48 hrs prior, handlers ignored alerts. AST: 13 min.
F-8	open grass field	10 C, 6 cm patches of snow, very light wind	dry human bone	5	66	dep. 48 hours prior, bones in water unrecov. AST: 11 min.
F-9	open grass field	3 C, isolated water patches, light wind	dry human bone, fluid on ground	6	94	dep. 48 hrs prior, no alerts on fluid. AST: 11 min.
F-10	woods, treed fields	6 C, some puddles, shifting light winds	dry human bone, fluid containers	6	86	articles deposited 48 hrs prior. AST: 17 min.

litter, ground cover, snow (care was taken to avoid leaving footprints to the hides) and water. All items were handled and placed in the search areas using large metal tongs. A total of 10 field trials were conducted from February through April, 1998. A summary of the environmental and weather conditions and scent sources for each training session and field trial is given in Table 8.2.

Scent sources included dry human and animal bone, sterile gauze or cotton soaked in human decompositional fluid (collected at autopsy) and placed in perforated plastic or metal containers, and small articles and clothing saturated in decay fluids then dried. All bone used had been desiccated, but had not been boiled or chemically treated. Fluid containers were prepared using latex gloves. No artificial or "pseudo" scents (Snyder Sachs, 1996) were used in this testing. All hides and scent sources were used one time only to avoid scent contamination.

Training the type of alert (to indicate a find) given by each dog was left to the discretion of the handler, provided the alert was aggressive and did not involve the animal touching, pawing or mouthing the hides. Examples of aggressive alerts used include barking or downing the dog. During the training sessions, the author and fellow handlers also made note of passive alerts (i.e. repeated sniffing of or urinating on unrecovered hides) to aid the handler in recognizing when the dog had found an item.

8.3 RESULTS

Overall recovery rate for the field trials was 81%, with a per-trial recovery rate ranging from 57 to 100%. The overall recovery rate for each individual dog team

ranged from 55 to 95%. Results for individual dog teams are given in Table 8.1. The results of the field trials are found in Table 8.2.

8.4 DISCUSSION

Previous reports suggest that environmental factors, primarily temperature, significantly affect dog performance (France *et al.*, 1997). Decreases in the dog's ability to scent have been noted at temperatures exceeding 29°C and it has been suggested that dogs may be unable to locate scent sources under snow or in freezing temperatures (France *et al.*, 1997). Results from this study indicate that low ambient temperature and snow depth appear to have no effect on the dog's performance. For example, one training session (T-7, Table 8.2) took place with ambient temperatures at -30°C and with sources located under 25 cm of snow. Although one dog was unable to search because the conditions caused pain in its paws, the remaining teams recovered 100% of the hides. Snow depth and conditions also did not appear to hinder dog performance. Trials/tests conducted on days with greater snow depths (T-7, F-4, F-5 from Table 8.2) had impressive recovery rates (90-100%), while searches conducted in less or no snow resulted in lower recovery rates. Written handler comments at the end of each exercise support these findings, indicating that the dogs will bury their noses in the snow and use scent contained within air pockets to locate the source. Findings presented here represent cold weather results only; moderate and warm weather climate testing is ongoing and will be reported separately.

Factors which did appear to affect team performance in this study include familiarity with scent source and experience in specific types of search area terrain. The decomposition of a body is a dynamic process, producing a variety of scents as decay progresses from bloating through skeletonization (Evans, 1968) and, ideally, training should familiarize the dog with the full range of decay scents from fresh to bone. Attempts were made during the field trials to introduce the dogs to progressively older, drier human bones (representing an increasing PMI). The reduced overall recovery rate seen in the eighth field trial (F8, Table 8.2) is due, in part, to the introduction of old, dry human bone to which the dogs had not been previously exposed. A previous study indicates that a dog's ability to match the odors of different body parts from one person may be a result of training focusing on the common elements (Schoon and De Bruin, 1994). This type of cadaver searching may represent a further test of a dog's ability to recognize similar yet differing odors from a single source and additional research is required to determine which decay elements the dogs are capable of recognizing.

Scent source type also influenced team performance. Dry bone elicited the strongest, most aggressive alerts from the dogs. Human bone was consistently found by all dogs, while several of the dogs gave only passive alerts or did not respond to animal bone. Human bone was the primary training scent source during this program and this may explain the discrepancy. Strong, consistent alerts were also given to clothing, although the previous Search and Rescue training of all the dogs prior to the cadaver training may explain their familiarity with recovering clothing articles.

Response to animal bone and decompositional fluid scent sources varied among the dogs and may be reflective of the level and consistency of a dog's training. Climatic conditions must also be taken into account when using fluid based scent sources; freezing temperatures may have affected or restricted odor distribution from the decompositional fluid. Results from warm weather testing may help in understanding these findings. Finally, the plastic scent tubes used in training session 4 (T-4, Table 8.2) were unsuitable for cadaver training as the tube shape was similar to the play reward toys many handlers used and the dogs continually retrieved the tubes.

Previous experience with specific environmental conditions also increases the likelihood of recovery. For example, the dogs had received no prior training in small article searching in shallow water and the first bones placed in puddles during the eighth field trial (F-8, Table 8.2) were not recovered. The dogs were directed to the submerged bones and, in the subsequent two field trials (F-9, F-10, Table 8.2), hides located in water were quickly located. A similar decrease in overall recovery rate was seen in the third field trial (F-3, Table 8.2) in which the teams were first introduced to searching in a dense wooded area.

Handler error or inexperience also played a role in overall recovery rates. The low recovery rate seen in the seventh field trial (F-7, Table 8.2) resulted from handlers repeatedly ignoring the alerts or indications given by their dogs. In this trial, 30 cc of decompositional fluid was deposited directly onto the soil at various locations within each search area. The dogs, having been exposed to the scent previously on small

articles, indicated the areas, yet the handlers ignored the alerts because they were unable to locate any visible scent source.

Scenes involving decomposed, scavenged remains are complex and variable. Postmortem insect and animal activity can result in both dry and fleshed elements being recovered from a single body (Galloway, 1997). Repeated canid scavenging can result in wide-spread dispersal of remains across varying terrain (Haglund *et al.*, 1989). Scent sources and environmental conditions were purposefully varied throughout the field tests to simulate this diversity. Results indicate the need for a thorough training program which would expose both dog and handler to a wide range of variables in terms of both body elements and scene terrain. Recommendations and guidelines for training scattered remains cadaver dogs have been published separately (Komar and Galloway, 1998).

8.5 CONCLUSIONS

Field test results presented indicate that properly trained cadaver dogs are an efficient, reliable tool in search strategies involving scattered, scavenged human remains. Dog teams can quickly and thoroughly search large areas, greatly reducing the amount of time and manpower required to maximize recovery of body elements.

The results of this training/research program have been used to develop cadaver dog certification guidelines for the RCMP Civilian Search and Rescue Service Dog Program, the first such certification program in Canada.

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9. CONCLUSIONS AND FUTURE RESEARCH

9.1 Conclusions

The primary goal of this research is to investigate taphonomic processes and mechanisms particular to a cold climate region with the aim of identifying and interpreting the artifacts of those processes in forensic death investigations. Using human case studies and animal analogy field experiments, this study examines decay rates, animal and insect modifications to remains and associated materials, the effects of hanging and body size on decomposition, time-since-death estimation and search methods which maximize recovery of remains. Comparisons between the human and animal studies offer some insight into the credibility and appropriateness of using specific animal analogues to study human decomposition.

This research was conducted in three phases. In phase one, results of a records survey from the Office of the Chief Medical Examiner in Edmonton showed that decomposition rates in cold climate regions are more rapid than previously reported. Skeletonization may occur in under six weeks in moderate summer temperatures and in less than four months in severe winter weather. Regardless of season, postmortem animal scavenging of remains contributes significantly to soft tissue decomposition. Findings from a second case file review demonstrated that outdoor hangings are not uncommon in Alberta and that the isolated nature of the hanging location occasionally results in delayed discovery and decomposed remains.

Using background information and parameters established during the first phase, an animal analogy field study was undertaken during the second phase of research. An

examination of the effects of body size on decomposition rates showed that the small sized carcasses normally used in entomological studies were inappropriate as models for human decomposition in this climate region. Results also suggest that significant differences in decay rates are to be expected between subadults and adults or between thin and obese adults.

Further observations from the animal model field study indicate that clothing disturbance patterns resulting from postmortem insect activity may mimic those derived from a perimortem sexual assault. Similarities in the appearance of changes produced through human action and those created by insects and carnivore may confound crime scene interpretation and careful examination of all evidence is necessary to accurately discern the agent responsible.

Examination of animal scavenging during the field study indicates that, contrary to a previous report by Bass (1997), birds such as magpies and crows are important scavengers in this region capable of dramatically affecting soft tissue decay rates. Birds proved to be significant vectors of transport and modifiers of scenes and remains. Differentiating bird scavenging from that of rodent and canid is important both in establishing proper search strategies scene as well as identifying bone artifacts.

A critical concept in actualistic field studies is the appropriateness and credibility of the animal analogies used (Gifford-Gonzales, 1989). The first two phases of this research offer a unique opportunity to assess the validity of using animal models, specifically domestic pigs, as analogues for humans in decomposition studies. Comparisons between a field study of suspended animal carcasses and case studies

described in the hanging records review indicate that animals and humans respond to taphonomic processes in similar fashions. Both experienced extensive desiccation of soft tissues as a result of environmental factors, as well as similar variations in insect and animal scavenging behaviour. Comparisons of suspended carcasses to surface deposited animals suggest that these postmortem artifacts may be characteristic of hanging and that one feature, the presence of a blowfly "egg collar", may be unique to hangings. Overall, the use of domestic pigs as analogues for humans in taphonomic field studies appears valid.

The third phase of this study again employed field studies to examine the use of cadaver dogs in locating isolated and concealed human remains, a problem commonly encountered by death investigators in this region. Field trial results show cadaver dogs to be a highly reliable tool, even in extreme winter conditions. The use of dogs in search strategies to locate scavenged remains can reduce the time and manpower needed to search large areas and maximize recovery efforts.

Results from this study provided background for a preliminary investigation of a potential new method of estimating the postmortem interval. The rationale and methodology for a histological analysis of the postmortem changes to biochemical components of intervertebral discs are presented in the appendix as a basis for a pilot study and further research.

9.2 FUTURE RESEARCH

The taphonomic processes investigated in this research have implications for archeologists and physical anthropologists, as well as for forensic death investigators. For example, bird scavenging has received little attention in the forensic and anthropological literature (Komar and Beattie, 1998). The bone modifications described in this study should be identifiable in archeological cases. Analysis of an archeological sample from an appropriate population could result in the first report of bird scavenging in the anthropological literature.

Additional field studies into the effects of hanging and body suspension are also needed. Specifically, an entomological study examining differences in insect colonization behaviour, sequences and community composition are necessary to determine whether entomological databases established using terrestrial models are applicable to cases involving partial to full suspension of the body.

Finally, further field studies into taphonomic processes unique to cold climate regions are warranted. Although preliminary research into the effects of freezing on decomposition has been conducted (Micozzi, 1986), additional studies using more appropriate animal analogues are needed to investigate the effects of overwintering, snow cover and repeated freeze/thaw cycles on decay rates and sequences.

Failure to recognize and interpret the artifacts of naturally occurring taphonomic processes may result in the inaccurate reconstruction of perimortem events (Haskell *et al.*, 1997). Studies which contribute additional information on taphonomic

mechanisms in previously unexplored climates or environments help to reduce the risk of misinterpreting artifacts and modifications in death scene investigations.

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**Appendix A: A PROPOSAL: AUTOLYTIC AND PUTREFACTIVE CHANGE
TO THE PROTEOGLYCANS AND TYPE II COLLAGEN OF
THE NUCLEUS PULPOSUS OF LUMBAR
INTERVERTEBRAL DISCS AS AN INDICATOR OF
POSTMORTEM INTERVAL**

A.1 INTRODUCTION

The estimation of time since death in forensic investigations is a crucial element in the identification of individuals in cases of advanced decomposition or skeletal remains (Yoshino *et al.*, 1991). While there are several methods for estimating short-range time since death, there is currently no accurate method for determining middle and long-range postmortem interval (Gallois-Montbrun *et al.*, 1988).

A review of recent cases involving advanced decomposition from Edmonton's Office of the Chief Medical Examiner (Komar, 1998) showed that intervertebral discs (IVD) were recovered in the majority of cases. This is consistent with previous reports that IVD are among the last soft tissues to decompose (Haglund, 1991; Evans, 1963; Gill-King, 1997), even in cases of aqueous deposition (Haglund, 1993), extensive carnivore scavenging (Haglund, 1991), high ambient temperature and insect activity (Galloway *et al.*, 1989).

Given their persistence and high recovery rate, IVD seem a logical focus of study in establishing middle and long-range time since death. A review of the morphological and biochemical structure of IVD, as well as evidence that decomposition proceeds from the outer annulus inward to the nucleus (Higuchi and Abe, 1987), suggest that a histological analysis of the matrix of the nucleus pulposus may reveal a decomposition

sequence which correlates to elapsed time and provide an accurate method of estimating postmortem interval.

A.2 REVIEW OF THE LITERATURE

The typical human IVD consists of an external, fibrous ring called the annulus fibrosis and a semi-fluid core termed the nucleus pulposus (Agur, 1991). Although different in texture, the boundary between the two is not clearly defined (Hukins, 1988) and may become indiscernible with increasing age (Panagiotacopoulos *et al.*, 1987b). In adults, the disc is avascular, with oxygen and nutrition diffusing from the blood vessels surrounding the cartilage plate and annulus fibrosis (Higuchi and Abe, 1987).

The human nucleus pulposus is formed of a gel of proteoglycans containing 5% collagen (Hukins, 1988), exclusively type II (Eyre, 1988). The proteoglycans, primarily chondroitin sulfate glycosaminoglycans covalently linked to a core protein, are responsible for the high water content of the nucleus, which ranges from 88% at birth to 65% by the eighth decade of life (McDevitt, 1988). Age-related reduction in water content is the result of a progressive decrease in glycosaminoglycan content (Hukins, 1988; McDevitt, 1988). The proteoglycans are bound by a link protein to hyaluronic acid, which in turn interacts with the collagen fibrils (Hukins, 1988; Eyre, 1988; Woodhead-Galloway, 1980).

Of all the connective tissues, the IVD sustains the most pronounced age-related changes in both structure and composition (Chatani *et al.*, 1993). The nucleus

pulposus becomes increasingly dense and the distinction between the nucleus and annulus becomes poorly defined (Panagiotacopulos *et al.*, 1987a, 1987b). An increase in the number of collagen fibers transforms the appearance of the nucleus to that of fibrocartilage (Panagiotacopulos *et al.*, 1987b). These degenerative changes begin in the third decade of life (Amonoo-Kuofi, 1991).

Long-term compositional changes to IVD have not been previously documented; short-range studies in both animals and humans indicate that macroscopic and microscopic autolytic changes are slow in both onset and progression. Putrefaction of dissected canine cervical IVD, stored in normal saline solution at room temperature, did not begin until 71.5 hours after death (Fitzgerald, 1975).

Two studies of postmortem changes in ultrastructures in the nucleus pulposus of mice and macaques have been reported (Higuchi and Abe, 1987; Hase, 1985). Chondrocytes and notochordal cells from Japanese macaques showed no changes 6 hours after death but changes to the chondrocytes were seen after more than 12 hours (Hase, 1985). Mouse samples also showed no changes at 6 hours and notochordal cells became necrotic after 24 hours (Higuchi and Abe, 1987). Neither study examines changes to the matrix, nor continues past 48 hours.

Autolytic and putrefactive changes to the major components of the nucleus pulposus - proteoglycans and collagen - have also not been widely studied. Preliminary results of one study using changes in the proteoglycans of synovial fluid as an indicator of time since death found the method worthy of further investigation (Hansen *et al.*, 1990). Differences in glycosaminoglycan concentrations and banding

patterns were detected between in vitro and postmortem fluid samples using a new method of agarose-acrylamide gel electrophoresis and sequential immunoblotting (Hansen *et al.*, 1990). Glycosaminoglycans in canine femoral bone showed no changes 72 hours after death (Veijlens, 1971). Proteoglycan release from cartilage is arrested if the incubation temperature is reduced to 4°C (Dipasquale *et al.*, 1985). Collagen decomposes into low-molecular peptides or amino acids by the successive degradation of various enzymes (Gries, 1974). The action of collagenases and proteases have been shown to be temperature (Woodhead-Galloway, 1980) and pH dependent (Gries, 1974). No postmortem changes were seen in corneal collagen fibers examined 24 hours after death, although an increase in interfibrillar space was noted (Kanai and Kaufman, 1973).

While the specific timing of IVD collagen and proteoglycans decomposition is not known, evidence suggests that the two components decompose at different rates. Bound water content in cartilage decreases with increasing postmortem interval (Nikkolaeva and Dubinskaia, 1981), which may correspond to the initial breakdown of proteoglycans, while slower collagen degradation is indicated by the persistence of desiccated discs on skeletal remains.

The biochemical composition of human IVD is unique. Notochordal cells, absent from adult human IVD yet persistent in other mammalian discs, renders direct comparisons between humans and animals invalid (McDevitt, 1988). Variations in collagen type and ratio due to bipedal stresses (Eyre, 1988) also argues against the use of animal analogies in this study.

A.3 METHODOLOGY

The research will be conducted in two phases using human IVD removed following postmortem harvesting of organs and tissues or autopsy.

A.3.1 Phase One - Descriptive

Initial investigation will focus on documenting and describing the perimortem appearance of stained specimens under light microscope, from samples harvested within hours after death.

Morphological and biochemical changes to human IVD after the third decade of life are well documented, with the nucleus becoming progressively more fibrotic and undergoing a significant reduction in water content (Eyre, 1988; McDevitt, 1988). Age cohorts within the sample will be established to control for these age-related changes. Initial age cohorts will separate specimens into groups aged 18 to 30 years and 30+ years; however, additional age cohorts, perhaps by decade, may be necessary to control for age-related variation.

Although a degree of sexual dimorphism has been demonstrated in vertebral bodies (Taylor and Twomey, 1984), no sex differences have been reported in the biochemical composition of IVD. Preliminary testing will determine whether significant sex differences are evident; if so, the sexes will be analyzed separately in subsequent experiments.

A.3.2 Phase Two - Comparisons with Known Time Since Death Specimens

Once the perimortem baseline has been established and age cohorts have been defined, samples will be obtained from individuals with a known elapsed time since death of 24 hours or greater. Samples for this phase will be obtained, upon the consent of the next of kin, from individuals following autopsy.

Although recent studies describing and identifying proteoglycans and collagen in cartilage have utilized the electron microscope (Hunziker and Schenk, 1987), the light microscope was deemed a more appropriate choice for this study because of its cost effectiveness and ready availability to forensic pathologists.

Recommended sample preparation procedures include cryofixation (Hunziker and Schenk, 1987). Staining for glycosaminoglycans with Alcian blue (as described in Braund *et al.*, 1976; Pousty and Butler, 1978) provides a measure of total glycosaminoglycan content. Low interobserver error was found in the scoring of regional staining intensity with Alcian blue (Braund *et al.*, 1976), suggesting the method has a high degree of reproducibility. Counter stains for collagen are hematoxylin and eosin (as described in McManus and Mowry, 1960).

Only adult discs (18 years and older) will be sampled. The third and fourth lumbar IVD will be removed from each individual following organ harvesting or autopsy and flash frozen for transport. Information will be recorded as to the age, sex and cause of death of each individual, as well as the elapsed time between death and disc recovery and the amount of time the body was stored in a refrigerated area.

Confidentiality of the individuals will be ensured as no personal information, such as

name or address, will be recorded for this study and all specimens will be labeled by file number only.

As dissection for sample preparation compromises disc structure, accelerating desiccation and bacterial exposure and thereby altering decomposition rates, each disc will only be sampled once. As the biochemical composition of discs within a region does not vary (Hukins, 1988), the third and fourth lumbar IVD were selected because of the ease of access for harvesting and their high recovery rate in forensic cases involving advanced decomposition.

A.4 RESEARCH OBJECTIVES

Limitations of the described methodology must be kept in mind; qualitative histochemical analysis is subjective, and the final interpretation is drawn from numerous microscopic fields (Braund *et al.*, 1976; Findlay, 1977). As a result, the expected goal of this research is a series of photographic images documenting the significant, sequential autolytic changes at specific intervals in postmortem time elapsed. A separate series for each age cohort (and sex, if necessary) will illustrate the normative early postmortem appearance of the nucleus and subsequent changes at each appropriate time interval, providing a comprehensive comparative method of determining time since death.

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Abstracts

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"The Use, Training and Reliability of Cadaver Dogs", Debra Komar. Invited guestspeaker at the 1998 Canadian Police Canine Association Seminar and Trials, Edmonton, Alberta, September, 1998.

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"The Effects of Age and Sex on Infracranial Non-metric Trait Frequencies", Lynda Wood and Debra Komar. Presented at the 23rd Annual Meeting of the Canadian Association for Physical Anthropology, Las Vegas, Nevada, November 1995 - Winner of the Davidson-Black Award for Best Poster.

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- May 1997, 1998 Lecturer/Co-ordinator, Forensic Archeology Course (5 day). Offered by University of Alberta Dept. of Anthropology, Office of the Chief Medical Examiner (Edmonton) and the Archaeological Survey, Provincial Museum of Alberta for law enforcement officers and medicolegal investigators.
- Sept. 1992 - Aug. 1993 Fossil Cast Maker, Miocene Hominid Project.
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Field Schools

- July 1993 Archeology of Great Britain, Dr. P. Werner - Field Director
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Selected Forensic Casework

- 10/98 **Homicide Investigation** - Battle River, Alberta. 2 day search of river valley for remains with cadaver dog team. Chief Investigator: Sgt. C. Smith, Major Crimes North, K Division RCMP.

- 10/98 **Homicide Investigation** - High Level, Alberta. 4 days of scene analysis, body recovery and exhumation (2 locations), analysis of remains. Preliminary and final reports submitted to OCME and entered into evidence at trial. ME file # 8273-98, RCMP file # 98-2723. Appeared as an expert witness for the Crown Prosecutor, Peace River Queen's Bench, March 11, 1999.
- 09/98 **Homicide Investigation** - Yellowknife, NWT. Scene and evidence analysis, bone identification. Chief Investigator: Cpl. M. Beaudoin, NCO I/C, GIS, G Division RCMP.
- 04/98 **Missing Persons Investigation** - Hobbema, Alberta. Scene analysis, recovery and analysis of remains. Preliminary report to OCME. ME file # 7805-98. Chief Investigator: Sgt. C. Smith, Major Crimes North, K Division RCMP.
- 01/98 **Suspicious Death Investigation** - Edmonton, Alberta. Scene analysis, remains recovery and exhumation, analysis of remains. 3 subsequent searches of area for additional evidence. Preliminary and secondary reports submitted to OCME. ME file # 6295-97. Chief Investigator: Det. B. Ducette, Major Crimes, Edmonton City Police.
- 10/97 **Homicide Investigation** - Sherwood Park, Alberta. Scene analysis, search and recovery of remains, remains analysis, 3 further searches for additional evidence. Preliminary report submitted to OCME. ME file # 8280-97, RCMP file #97-7200.
- 10/97 **Suspicious Death Investigation** - Edmonton, Alberta. Analysis of remains. Preliminary report submitted to OCME. ME file # 8224-97.
- 09/97 **Homicide Investigation** - Sherwood Park, Alberta. Analysis of remains. Preliminary report submitted to OCME. ME file # 8147-97.
- 01/97 **Homicide Investigation** - Cooking Lake, Alberta. Search for clandestine grave. Chief Investigator: Sgt. K. Simmil, Major Crimes North, K Division RCMP.
- 09/93 **Homicide Investigation** - Orangeville, Ontario. Search for remains, scene investigation. Ontario Provincial Police, Office of the Chief Coroner, Toronto.

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- 1997 - present Department of Anthropology Council Member and Elected Graduate Student Representative, University of Alberta.
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Province of Alberta Graduate Fellowship
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Graduate Student Conference Award
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